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THESIS

A HORIZONTAL SPATIAL REQUIREMENT
STUDY OF THE GULF STREAM AS
MODELLED BY THE IFDPE ACOUSTIC MODEL

Katherine L. Cease

March 1987

Thesis Advisor: Alan B. Coppens

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A Horizontal Spatial Requirement Study of the Gulf Stream as Modeled by the IFDPE Acoustic Model

by

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requirements for the degree

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ABSTRACT

The sampling increment in horizontal spacing for a range-dependent environment was studied with respect to accurate prediction of propagation loss through a frontal system. A transmission loss model was verified by comparing its predictions with experimental data when the sampling increment was very small. A study of the effect of altering the sampling increment produced a maximum increment which retained a reasonable agreement with the prediction for very small incrementation. Sensitivity studies were performed at three source depths to determine depth dependency.

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I. INTRODUCTION

The commander at sea is required to have the most up-to-date environmental information available to enhance his use of ASW performance prediction systems. Accurate environmental information enables the acoustic models in the ASW system to accurately predict the propagation track of acoustic energy and thus allow optimum deployment of acoustic sensors.

Transmission loss models require environmental data as input. The more accurate the environmental input, the more accurate the simulation of acoustic propagation will be. This study is concerned with the trade-off between predictive accuracy and accuracy of the environmental input to an acoustic model.

Environmental inputs to an acoustic model consist of representations of the speed of sound profiles, bottom topography, bottom composition, and sea surface roughness as functions of space. This study will be concerned with the required spacing in range of the speed of sound profiles. Sound-speed profile data exist in the form of climatology, historical information, and on-scene XBT (Expendable Bathythermograph) and XSV (Expendable Velocimeter) readings. On-board ASW acoustic predictive systems currently use range-independent acoustic models. These models accept only one SSP (sound speed profile), a flat ocean bottom, and a single bottom description. The next level of sophistication of acoustic modelling is range dependency. Range-dependent models require realization of the environment as a function of range. The goal of this study is to contribute to the support of range-dependent models.

Systems now available cannot provide on-board, real-time information that the operational commander can use in complex ocean environments. Usually, data collected by platforms are sent to a shore-based facility to be entered into a model which is then run and the results transmitted back. During this interval, the tactical situation can change significantly. What is required is a method of performing these calculations on board and in a timely fashion. The next generation of platform systems should provide this capability, in-situ.

Range-dependent modelling requires a considerable amount of input data. One method of supplying such data is ocean dynamic modelling. It is planned to combine maturing technologies into a system that will ultimately produce information for use in tactical scenario models. (See Fig. 1.) Data from in-situ and remote sensors will be fed into dynamic ocean models which will then produce information used in acoustic models and then into tactical scenario models. The general question pertinent to this study is the determination of the amount of information required from the ocean dynamic models. The question is a broad one; this study examines one specific aspect of the general environmental question. What is the maximum spacing in the horizontal sound speed field that can yield an acceptably accurate acoustic field?

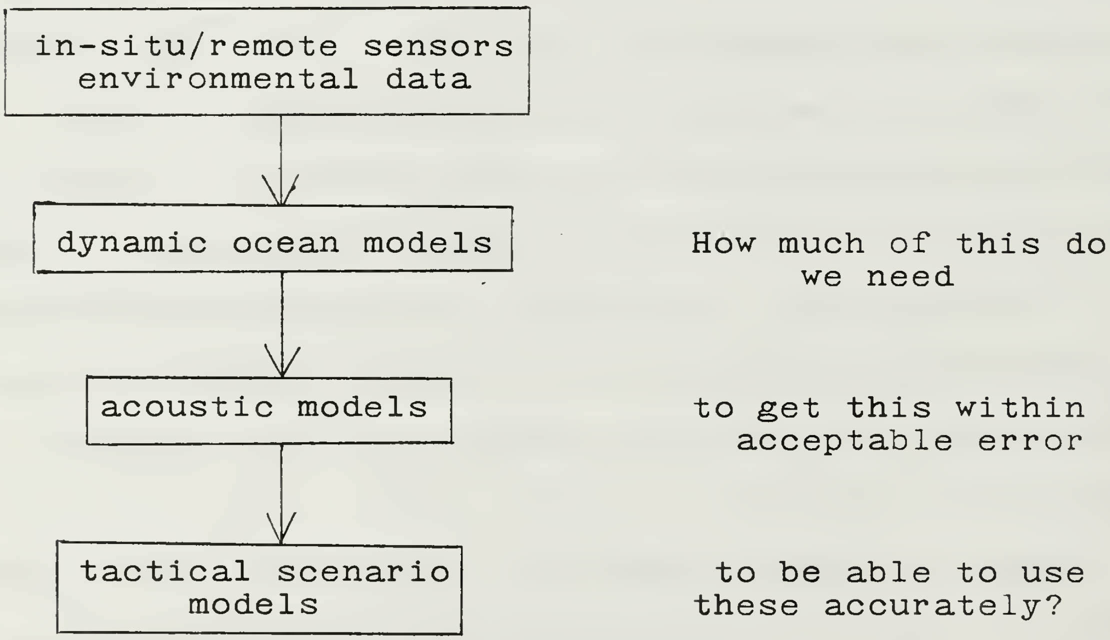


Figure 1. Combining Maturing Technologies

Current acoustic performance prediction systems, such as ICAPS (Integrated Carrier Acoustic Prediction System) and SIMAS (Sonar In-Situ Mode Assessment System), incorporate the range-independent model RAYMODE. As the systems are upgraded, a new generation of software will include the range-dependent models. This requires a more detailed environmental data base than we now have.

Specifically, we must know what is the cost in acoustic predictive accuracy if we go to larger and larger spacings in the sound speed field, both horizontally and vertically (vertical resolution is not the subject of this study). Tactical cost, computer memory and execution time are key factors, but also because use of such models is scenario dependent. Each scenario may require different spatial resolutions. A resolution too fine is a waste of valuable resources; a resolution not fine enough may affect tactical operations.

Once the problem had been defined, a procedure was needed to solve the problem. Because this study concerned the extraction of environmental data for the purpose of predicting acoustic performance, it was essential to find an environment suitable for use.

In determining what was important in horizontal spacing, an environment was chosen that would describe a worst-case scenario. Sharp gradients found in large oceanic frontal systems (e.g. the Gulf Stream) pose unique problems, as well as require a more exacting description of the environment. Such an environment was found in the Gulf Stream Frontal Experiment (GSFE, Ref. 1). In addition to the experiment being carried out in a frontal region, acoustic data were simultaneously obtained which were valuable in the model verification (see Chapter Three).

Once an environment was chosen, the IFDPE (Implicit Finite Difference Parabolic Equation) Model (Ref. 2) was chosen for the horizontal spatial requirement study. IFDPE satifies several requirements: 1) it is range-dependent, 2) it does not have any limitations on the amount of environmental data (other than machine limitations) input, 3) it has a good reputation for handling complex environments, and 4) it produces a full simulation of the acoustic field at all depths and ranges.

Finally, a procedure was established to complete the mechanics of the study in the form of computer program execution and analysis. The history of the IFDPE model had shown its utility and accuracy, but this was verified to ensure it was the "right tool for the job". Input files were established (more detail in Chapters Two and Four) and executed based upon a uniform range spacing and using the 2 km resolution as a baseline.

This report breaks down into further chapters with accompanying appendices. Chapter Two details the history of the IFDPE model and why it was the model of choice for this study. Chapter Three details the verification of the model. Chapter Four details the interpolation of SSPs required, the candidate range spacings chosen for program execution, and the graphical output from the model. It also covers in detail the IFDPE input runstream and the sensitivity studies that were performed. Chapter Five analyzes the results of the statistical output of transmission loss difference graphs based upon criteria arbitrarily established by the authors. Chapter Six gives a brief conclusion to the study, inviting areas for further research.

II. BACKGROUND AND DEVELOPMENT OF IFDPE

Most current operational acoustic models used are range independent and cannot adequately describe the acoustic field.

Some models, such as Critical Angle PE (Parabolic Equation), PAREQ (Ref. 3, 4), and IFDPE are range dependent. Critical Angle PE does not handle bottom interaction well (it is poor for bottom bounce conditions); PAREQ handles bottom interaction well but not as well as IFDPE. IFDPE deals well with bottom interactions. More recently, other models such as RAREQ (Range Refraction Parabolic Equation) and the wide-angle IFDPE range dependent models have been developed (Ref. 5, 6).

Determining the path and strength of an acoustic signal requires solving the wave equation or an approximation to it. One of the easier approaches to an approximate solution is the parabolic equation approximation.

A. THE PARABOLIC EQUATION

The parabolic equation approximation is derived by assuming an acoustic pressure field of constant frequency. This reduces the wave equation to the time independent Helmholtz equation. Assuming cylindrical symmetry, applying some range restrictions, and assuming that the variation of sound speed profile and bottom properties are sufficiently gradual, reduce the Helmholtz equation to a parabolic wave equation (Ref. 7).

The parabolic approximation is equivalent to neglecting backscattering since the values for small r (range) are not dependent upon the subsequent values obtained for larger r (Ref. 7).

Solutions to this parabolic equation may be found by incrementally increasing range ("stepping out the range solution") and solving because now "the entire acoustic field does not need to be solved for all relevant ranges and depths 'simultaneously' subject to boundary conditions on a surface surrounding the volume of interest" (Ref. 7).

One of the limitations of the simpler PE model is that the source angle is restricted to +/- 20 degrees, after which the approximation breaks down. This is a narrow beam width, and energy passing out of this angle cannot be accounted for. Extensions of the PE allow for +/- 40 degrees but are presently not implemented in operational TL models.

An early solution to the parabolic equation, introduced by Tappert and Hardin, was the split-step

Fast Fourier Transfer algorithm. This method is fast and accurate when the field interacts only weakly with the ocean bottom. It is less accurate when the field reacts strongly with the bottom; it has difficulty handling density or sound speed differences between two media (Ref. 2). The latter difficulty can be overcome but only with very long computer execution time.

B. IFDPE MODEL

In 1975, the Crank-Nicholson implicit finite difference (IFD) method for solving the parabolic equation was introduced by Lee and Papadakis. An IFD method was chosen over an explicit finite difference solution because the IFD solution is unconditionally stable, consistent, and converges to the theoretical solution as the range and depth increments tend to zero (Ref. 8). The IFDPE solution based upon the Crank-Nicholson method uses a second order central difference formula and places the problem in the form of a tridiagonal matrix.

The model chosen for this acoustic study is the IFDPE (Implicit Finite Difference Parabolic Equation) Model (Ref. 2). The program was written in Fortran for use on the VAX-11/780 computer.

The IFDPE model used in this study is the wide-angle version (Ref. 9) which allows a beam angle of +/-

40 degrees and thus enable the user to generate output for near-field study. (However, energy still escapes from this beamwidth which cannot be accounted for and thus is a drawback to IFDPE.) Technically, this version is no longer in parabolic equation form, but a pseudo-partial differential equation. The acoustic modelling community uses the PE nomenclature for this model and this report adheres to this convention.

The model can handle the following environments:

1) range dependent/range independent
2) shallow water/deep water
3) shallow-to-deep water, deep-to-shallow water, or the combination

IFDPE essentially solves the problem in layers: a water column underneath a pressure-release surface; a water-bottom interface: multiple layers in the bottom, and; an artificial acoustic basement (absorptive layer) overlying a pressure-release boundary. Both a pressure release surface boundary condition and a pressure release boundary condition at the greatest retained depth are required to terminate the solution within a finite depth interval. The basement attenuates the energy so that it is negligibly small when it encounters the bottom pressure release boundary. This ensures negligible spurious reflection back into the water column.

Each layer used in IFDPE contains an arbitrary sound speed structure (sound speed profiles provided by the user), constant density and constant attenuation.

Once the layers are defined, a program known as SSPBT (developed by NORDA oceanographers) couples the geoacoustic bottom to the water column to produce an input format easily manageable for use in creating input files for IFDPE.

C. SAMPLE IFDPE OUTPUT

Once the entire IFDPE input file is established (Chapter Four, Section A), the program is executed. Output is for all depths and ranges of the acoustic field. A sample grayscale plot is shown in Fig. 2. The darkest gray dot corresponds to a transmission loss of 100 dB or greater, decreasing in 10 uniform levels to the lightest shade of gray which represents losses of 50 dB or less.

Some features of this graph are readily apparent: the relatively flat ocean bottom at 5000 m depth, the energy propagating into the sediment layers to a depth of about 7000 m, the first convergence zone between 50 and 60 km, and the ray paths the acoustic energy followed. Also notable are the very black triangles near the source (one at the surface at around 10 km, the other penetrating down into the sediment from 0-10 km). These are areas where the acoustic energy could not be accounted for because of the source angle limitation in IFDPE. At larger range, this high angle energy would be greatly attenuated by multiple reflections from the bottom. Its absence thus does not significantly affect the sound field.

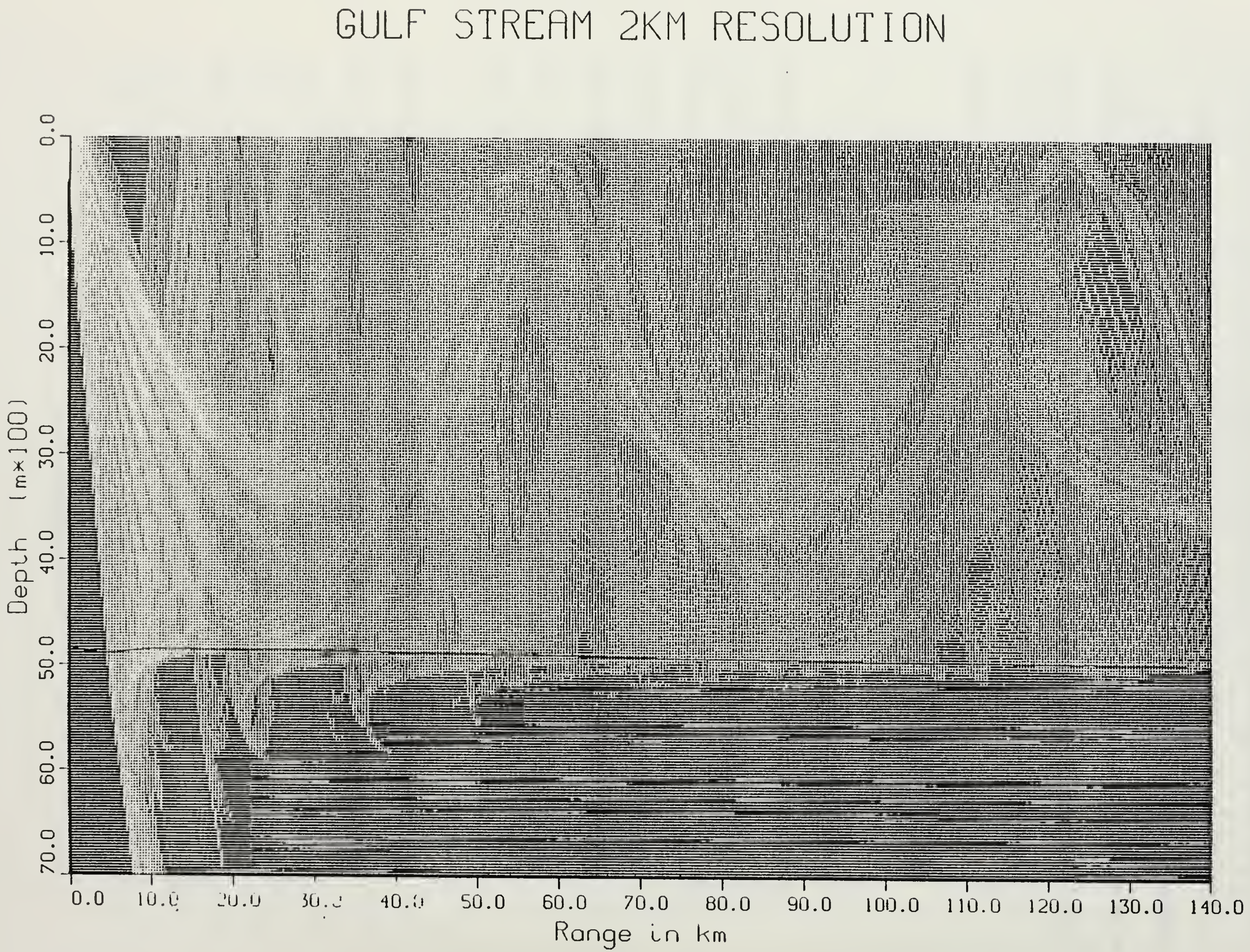


FIG. 2 Grayscale Plot 2 km Baseline Resolution

III. MODEL VERIFICATION

To ensure that the model used was appropriate for predicting acoustic propagation through the Gulf Stream, IFDPE was tested by comparing its predicted transmission loss with that measured from the NORDA/NUSC GSFE (Gulf Stream Frontal Experiment, Ref. 1). GSFE did two things--it provided the environmental data the study required and the transmission loss values needed for the computer model runs and analysis.

A. GSFE

The purpose of GFSE was to acquire an environmental/acoustic data set to evaluate the impact of the Gulf Stream frontal boundaries (North Wall and South Edge) on ASW/USW platform and weapons sonar systems performance.

Two ships were used--one as a source platform (using a multi-frequency transducer assembly capable of transmitting signals at two frequencies simultaneously), the other as a receiving platform using a six-hydrophone vertical line array (Fig. 3). Four tracks were laid out--three travelling through the Gulf Stream; the fourth, south in the Sargasso Sea (Fig. 4).

The source ship opened and closed range radially with the receiving array. It also conducted extensive XBT and XSV samplings of the various water masses. XBT drops from the receiving vessel were made about every two hours and at least one SST/SSP cast at each station.

Only data generated by the 310 Hz source were used for the verification test for two reasons: 1) higher frequencies require much longer program execution time (on the order of several hours on the VAX-780), and 2) if the model proved valid at 310 Hz, then it would also be valid at the lower frequency of 100 Hz used for this study.

B. VERIFICATION PROCEDURE

The environmental data for the four tracks (SSPs and bathymetric profiles) were first merged to create four input files for IFDPE program execution using SSPBT. SSPBT links the geoacoustic bottom data with oceanographic data for the particular area of the North Atlantic being studied (Table 1). SSPBT merges the SSP at its specific bathymetric point with the ocean bottom to provide continuity with the travelling acoustic wave, i.e. it couples the geoacoustic bottom to the water column. Once the data were merged, each track profile was then run through the IFDPE model. A plot of transmission loss versus range was generated and compared to the measured TL plots provided by GSFE.

Comparisons between model TL output and GSFE environmental data are shown in Figures 5-8.

C. RESULTS

The model fits the data well. The measured data were extracted from the GSFE TL graphs and plotted on the same axes as the TL values predicted by the model. Since the measured data were available only in graphic form, some error was introduced, but it should not be significant. The GSFE data points fit well as is evident from a visual examination of each graph.

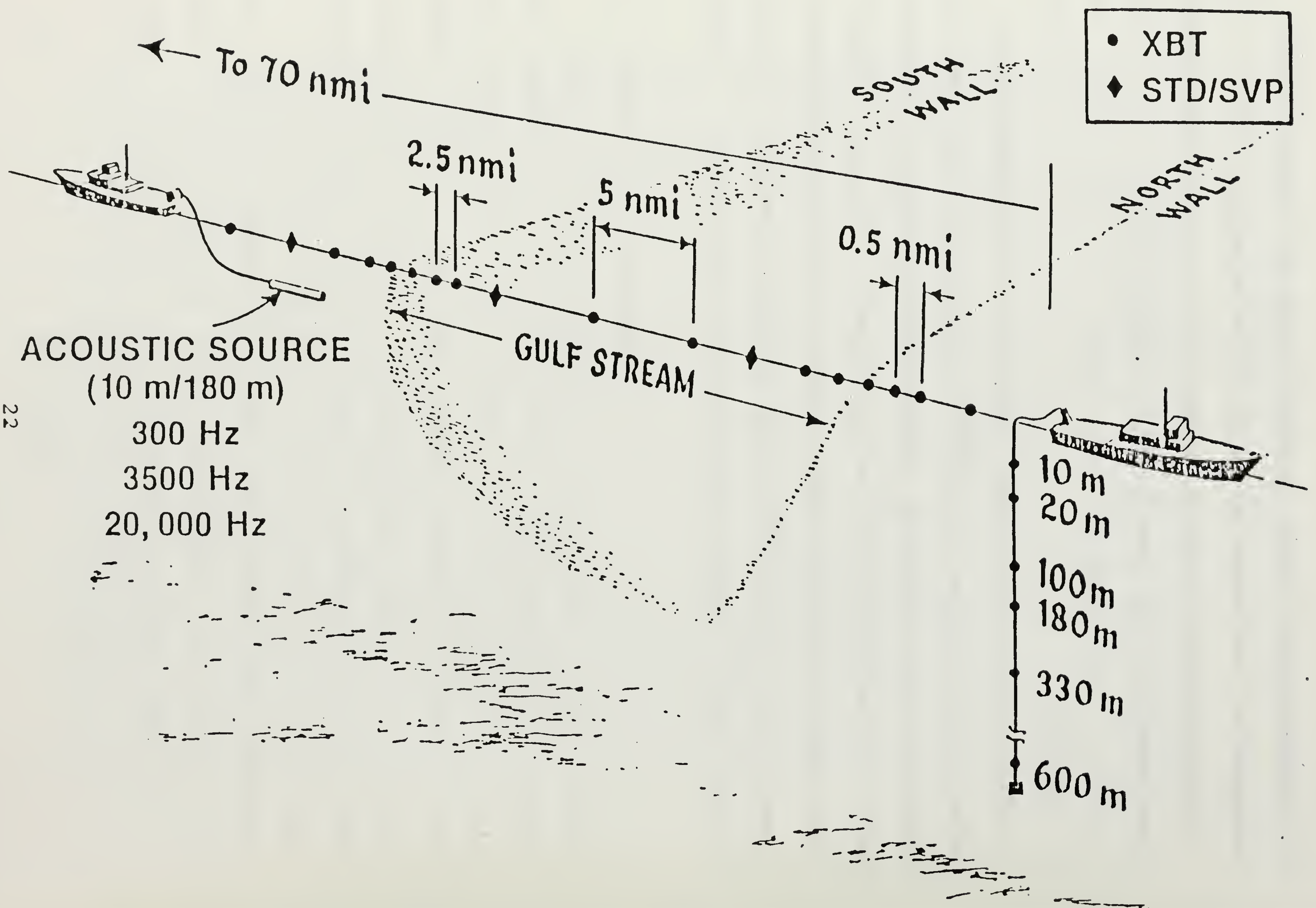


FIG. 3 GSFE Set-up (NUSC TM 811054)

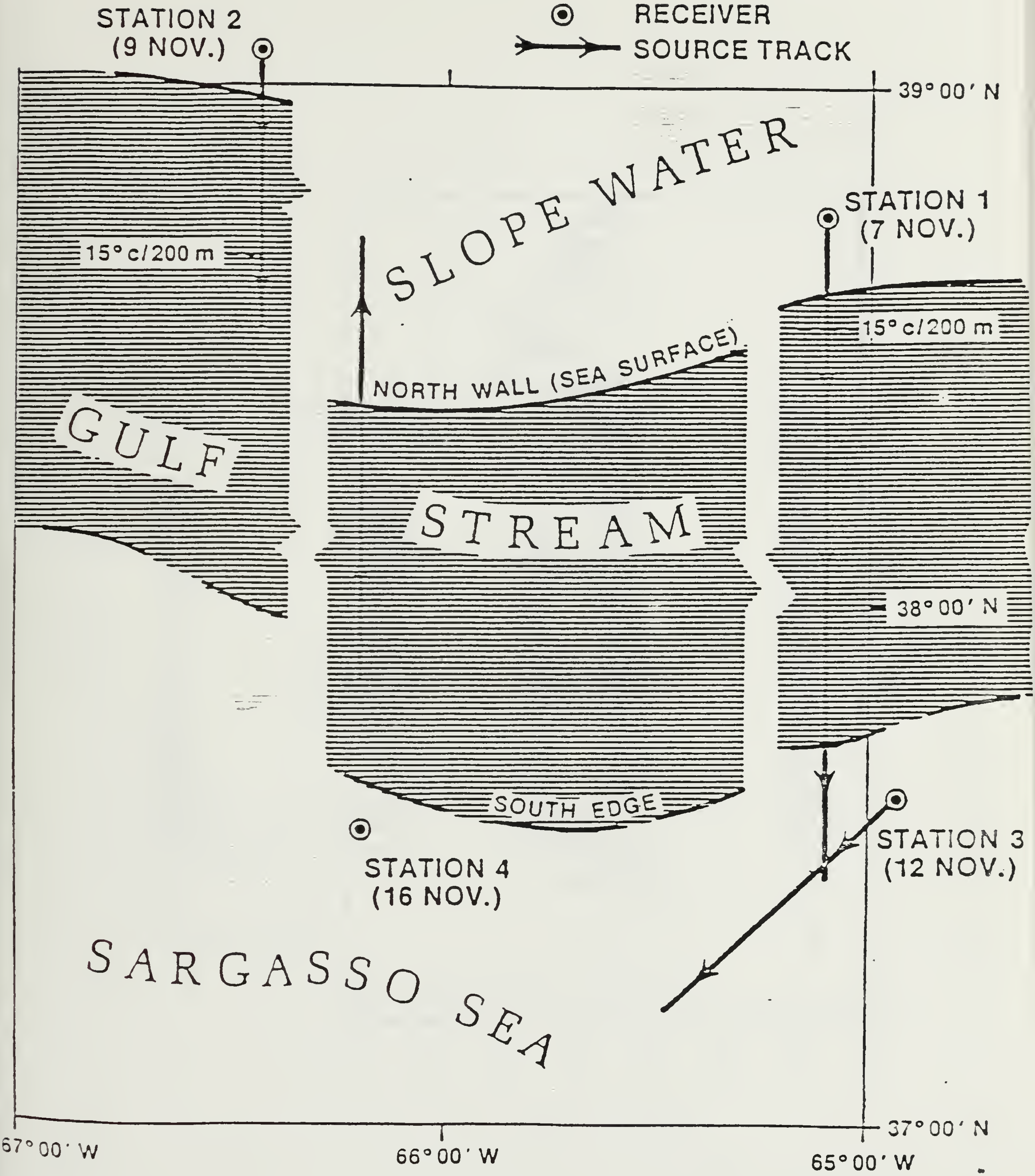


FIG. 4 GSFE Tracks Lay-out (NUSC TM 811054)

TABLE 1

GEOACOUSTIC BOTTOM MODEL

DEPTH M	VELOCITY M/SEC	ATTENUATION DB/HZ/KM	DENSITY G/CC
0	1487	.0045	1.50
25	1519	.0060	1.53
50	1550	.0075	1.57
75	1581	.0090	1.60
100	1610	.0110	1.64
125	1638	.0120	1.67
150	1665	.0130	1.70
175	1691	.0140	1.73
200	1716	.0150	1.76
250	1763	.0170	1.81
300	1805	.0190	1.86
350	1842	.0195	1.90
400	1874	.0190	1.94
500	1922	.0160	1.99
600	1952	.0130	2.03
800	2012	.0130	2.16
1000	2072	.0130	2.16

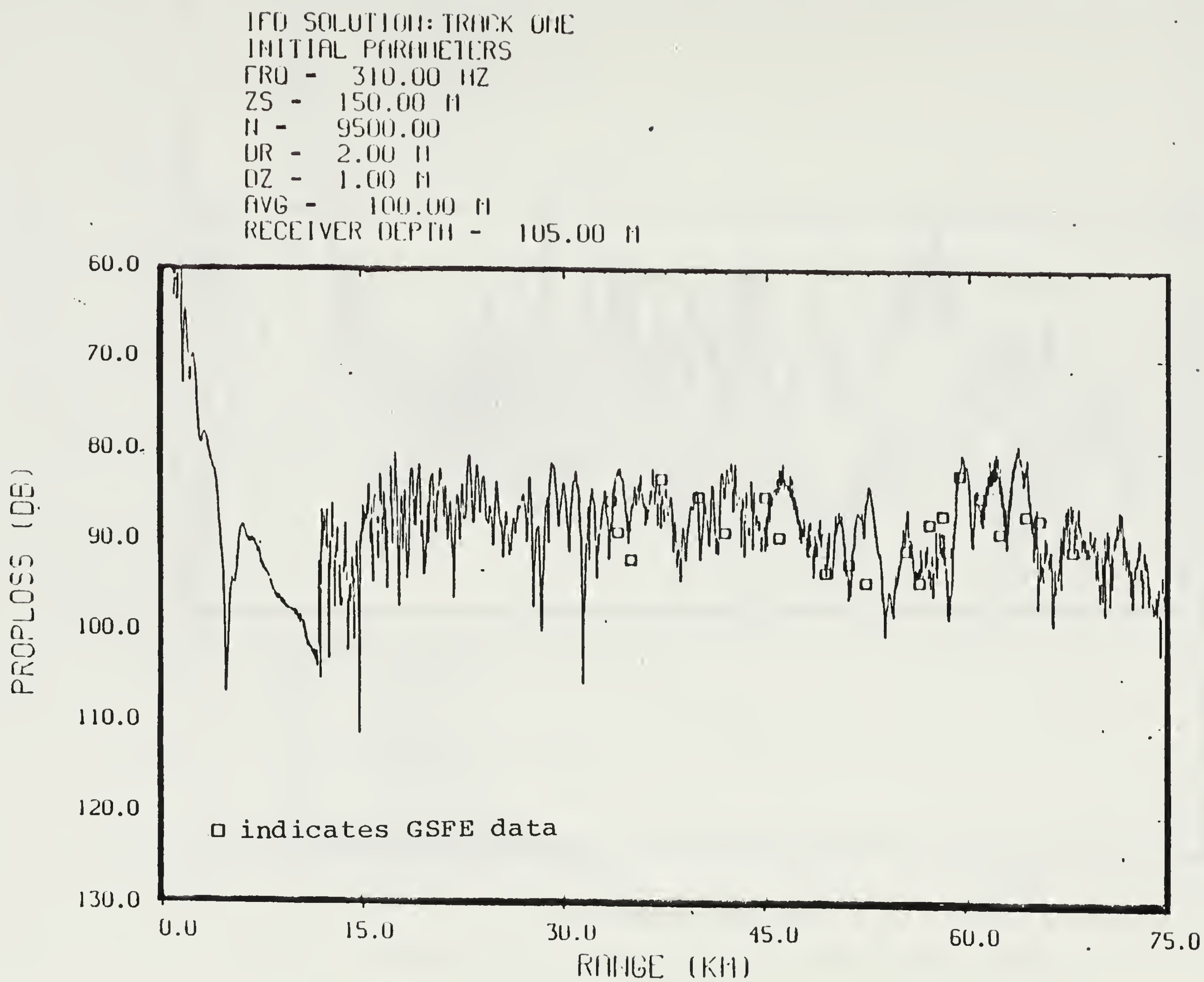


FIG. 5 Model TL vs Experimental Data Track One

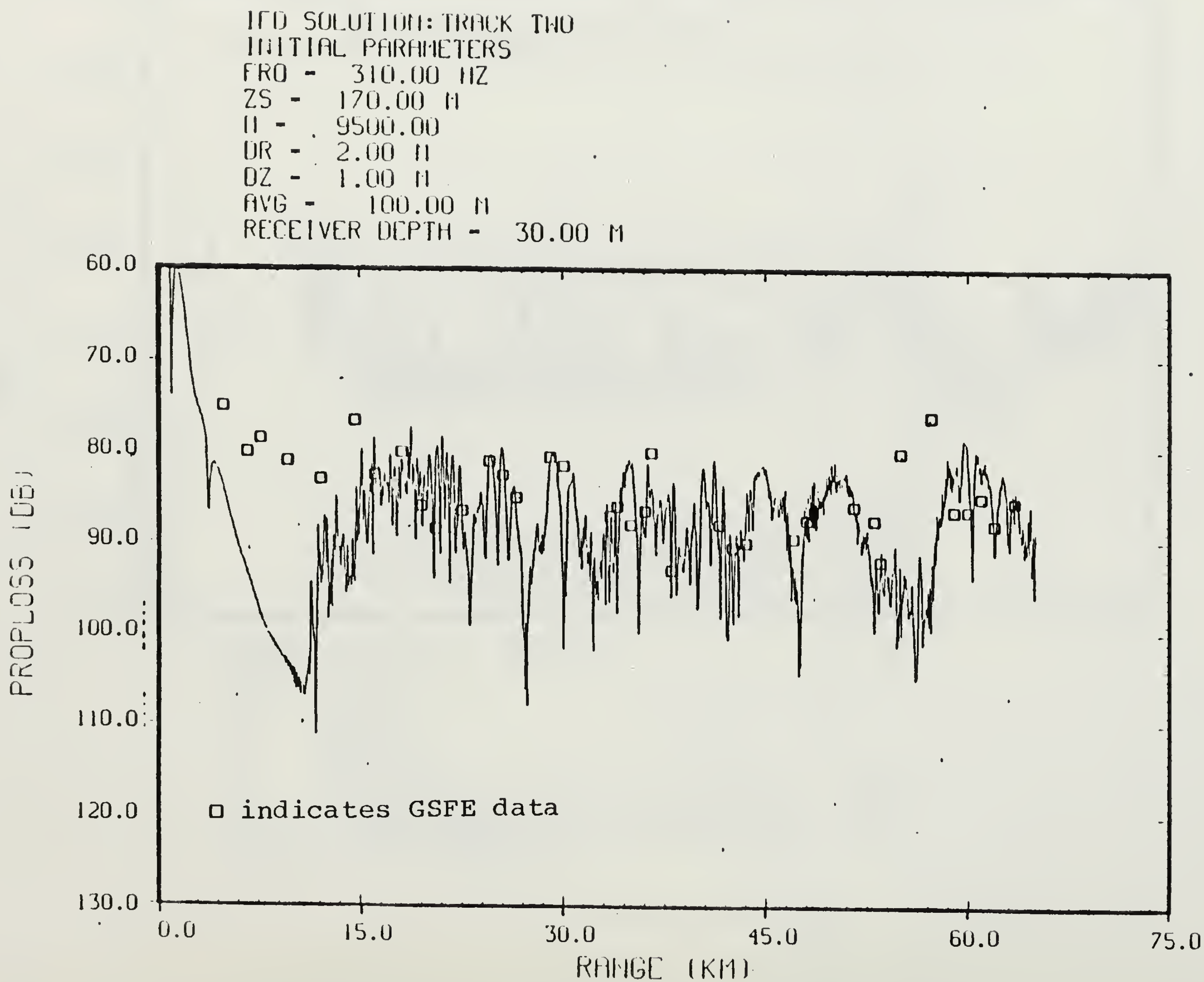


FIG. 6 Model TL vs Experimental Data Track Two

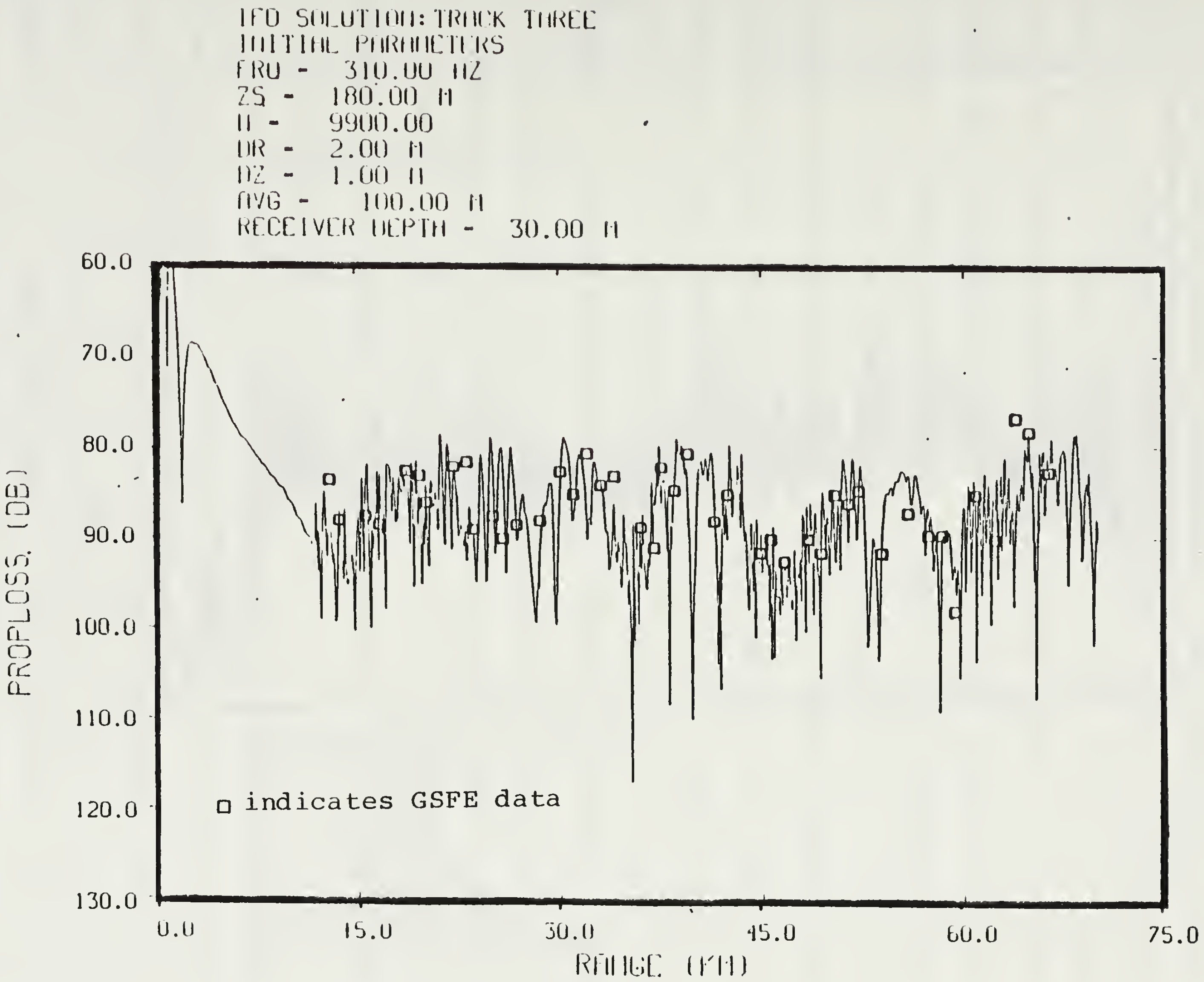


FIG. 7 Model TL vs Experimental Data Track Three

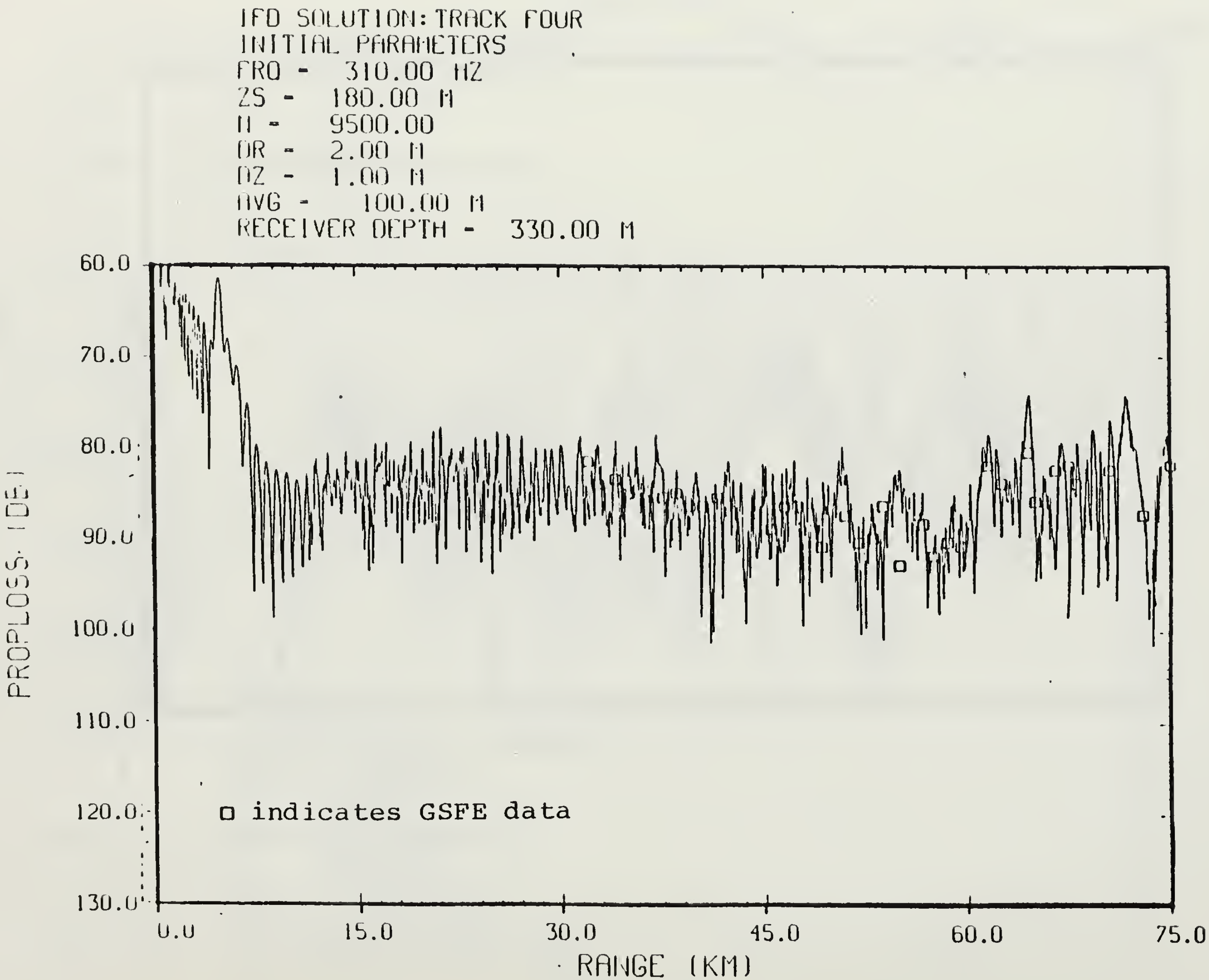


FIG. 8 Model TL vs Experimental Data Track Four

IV. HORIZONTAL SPATIAL REQUIREMENT STUDY

With verification complete, the resolution study began. However, some problems were encountered immediately. Practical considerations dictated that only one track be used to perform the study. Track One was chosen because it ran from the Slope Water into and through the Gulf Stream and entered the Sargasso Sea. It was also chosen because it presented the most complex sound speed field of the environments. The measured SSPs were not uniformly spaced in range, so they had to be supplemented by a sound speed profile interpolation routine (CFIELD, Appendix B, a part of RAYWAVE II, Ref. 10) to provide SSPs at uniform range intervals. SSPs were thus obtained at roughly two km intervals over the approximately 150 km range covered. There were 18 experimental SSPs and an additional 49 SSPs were interpolated (see Appendix C for a sampling of interpolated profiles).

After careful examination of each SSP, including those interpolated, the North Wall of the Gulf Stream was determined to be at 25.9 km downrange from the first SSP. No sea surface temperature (SST) data were available, so the location of the North Wall was determined strictly from the SSPs (Ref. 11). The profiles showed that the Gulf Stream's South Edge was not easily identifiable because it was not well-defined. However, it appeared to be at approximately 77 km from the initial SSP taken and this was the value used (Ref. 11).

For this study, a 100 Hz source was placed at depths of 100 m, 500 m, and 1000 m.

The candidate range spacings included executing IFDPE input files established at 2, 4, 6, 8, 10, 20, 30, and 60 km. A 2 km spacing was chosen as the baseline spacing for numerous reasons. First, the model requires large computer memory and any finer resolution would probably be (and, indeed was found to be) overkill. Second, the oceanography is not well known at any finer resolution. Third, only oceanographic models can support such a fine resolution. The spacings chosen for the 10-30 km range were for reasons of economy but had to include the 25 km range because this was the position of the North Wall of the Gulf Stream. It was necessary to keep the North Wall and the first sound speed profile fixed so that errors would not be introduced because of their manipulation. Every 30 km was sampled to determine how the static data base would handle the horizontal requirement. Finally, a 60 km sample was chosen to simulate the Navy standard data base which is resolved to 0.5 degrees.

Once the SSPs needed were interpolated, they were combined with the original SSPs to form the first part of the input files required to run the IFDPE model. Each input file was created using the Track One profiles at range spacings of 2, 4, 6, 8, 10, 20, 25, 30, and 60 km. In addition to the 2 km baseline, range spacings were obtained by deleting baseline sound speed profiles that occured between the desired spacings. For example, the 4 km sample was generated by deleting every other sound speed profile. Each sample was then processed according to the method established in the verification procedure.

For each sample resolution chosen, the distances between successive profiles were not exact, as shown in Table 2. Table 2 lists the ideal sample distances versus the true average distance actually computed and used in the study.

As the spacings were opened up (grosser resolution), it was critical that the field be produced on the same size grid (otherwise, TL differencing would not be possible). This indicated how well the field was resolved. In each input runstream (see below), therefore, depth and range grid spacing were kept constant.

Each input file was executed to produce nine acoustic fields. These fields were then used to create grayscale and TL difference graphs (Appendix D). Each output file was initially pre-processed by PREGRAY. PREGRAY averaged the intensities of the sound speed field over a given area. The area averaged can be found from the PREGRAY log output file and is represented as a gray dot in the plots. Each gray dot represents the same averaged area only if the same type of plot (grayscale or TL difference) created was the same. In this case, each gray dot for grayscale plots represented an area 18m deep X 350m long and for transmission loss difference graphs, 9m deep X 2450m long.

Each grayscale graph was plotted with a minimum TL of 50 dB and a maximum TL of 100 dB and to a maximum depth of 5000 m. In each TL difference graph the maximum difference plotted between two samples was treated as no more than ten dB and the minimum difference (obviously) no less than zero dB. To generate each TL difference graph, the intensities were subtracted from the 2 km baseline sample; those differences were converted to transmission loss values. In this way, TL difference graphs were produced for 4, 6, 8, 10, 20, 25, 30, and 60 km. For example, the 4 km sample was created by subtracting the 4 km intensities from the 2 km intensities values (Fig. 9). TL difference graphs were plotted only to a depth of 1000 m, since instabilities generally show up in the upper 1000. These figures were useful for qualitative but not for quantitative analysis. They were used primarily to qualitatively assess the horizontal spatial requirement needed, prior to more detailed quantitative analysis. Additionally, the TLDIF program tabulated the number of gray dots within a certain dB bin, arbitrarily defined by the program. Appendix E contains all the TL difference graphs. Histograms were then produced from these data.

The above restrictions were applied in order to prevent the graphs from becoming "cluttered". These particular limits were chosen after experimentation with other values to produce uncluttered graphs.

A. IFDPE INPUT RUNSTREAM

The input runstream is prepared in free format as follows:

FRQ, ZS, CO, ISF, RA, ZA, N, IHNK, ITYPEB, ITYPES
RMAX, DR, WDR, WDZ, PDR, PDZ, ISFLD, ISVP, IBPOT
A, B, C, D

where

FRQ = Frequency (Hz), a 100 Hz frequency was chosen as representative.

ZS = source depth (m), 100 m was chosen for the validation and resolution study; 500 m and 1000 m were chosen for the sensitivity studies.

CO = reference sound speed, a zero was chosen which sets the sound speed to the average sound speed in the layer.

ISF = starting field, a Gaussian starting field was assumed.

RA = horizontal range (m) from source depth to starting field; starting field was assumed to be the initial source range, i.e., 0.0.

ZA = depth (m) of starting field at RA, 9900m.

N = number of equispaced receivers in the starting field, 3300.

IHNK = Hankel function flag, since starting field is Gaussian, IHNK is set to 0.

ITYPEB = type of bottom, 0 sets the bottom type to that supplied by the user.

ITYPES = type of surface, 0 sets the surface as a pressure release surface.

RMAX = maximum range (m) of solution, for this study, maximum range was 150,000 m.

DR = range step (m) for marching solution, 5m.

WDR = range step (m) at which solution is written on disk, 50m.

WDZ = depth increment (m) at which solution is written on disk, 9m.

PDR = range step (m) at which solution is written, 10,000m.

PDZ = depth increment (m) at which solution is written, 4,000m.

ISFLD = 0, don't print starting field.

ISVP = 0, don't print sound speed profile.

IBOT = 0, don't print bottom depths.

A = 1.0

B = 0.75

C = 1.0

D = 0.25

A, B, C, and D turn on the wide-angle option for IFDPE.

The rest of the input runstream consists of the merged files including the water sound speed profiles, bottom bathymetry, and sound speed profile, density and attenuation for each bottom layer.

B. SENSITIVITY STUDIES

After the IFDPE runs were made and a general idea of the resolution range was ascertained, two extra source depths were executed, to determine if the horizontal spacing required was dependent upon source depth. The identical IFDPE input files for the verification and resolution studies were used but the source depths were changed to 500 m for the first depth and 1000 m for the second depth. Input runs were made only for the 6, 8, 10, and 20 km samples because the results indicated that the resolution required was approximately 8 km.

C. HISTOGRAMS

Figure 10 tabulates the percentage of transmission loss values that fall into a TL (dB) range for the 2 and 4 km difference spacings at a 100 m source depth.

Obviously, no TL values could be less than zero. However, any TL values greater than 9.17 dB were put into the same bin. Bins in between 0 and 9.17 dB are delineated at 1.87, 2.92, 3.96, 5.0, 6.04, 7.08, 8.13, and 9.17 dB. For all the histograms of TL differenced values, see Appendix F.

TABLE 2.

IDEAL VS TRUE DISTANCE USED IN SAMPLES

SAMPLE	AVG DISTANCE
2 km	1.9495 km
4 km	3.8834 km
6 km	5.8254 km
8 km	7.8385 km
10 km	9.8583 km
20 km	16.7783 km
30 km	
60 km	

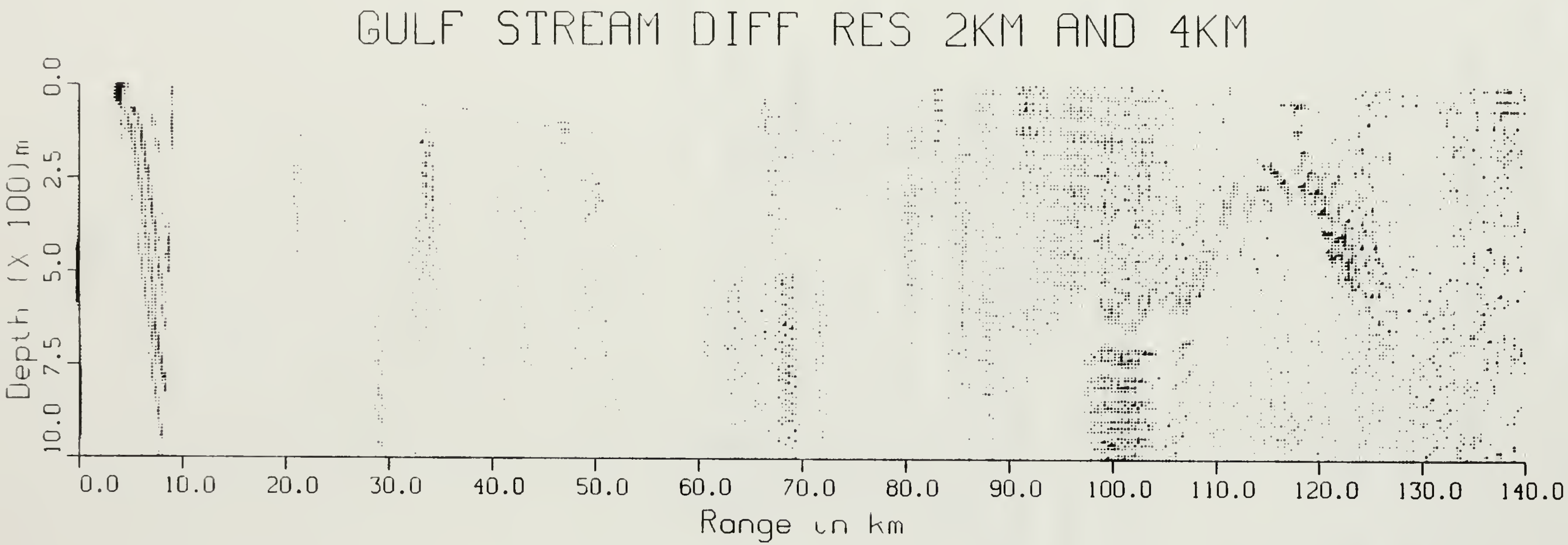


FIG. 9 2-4 km TL Difference Sample

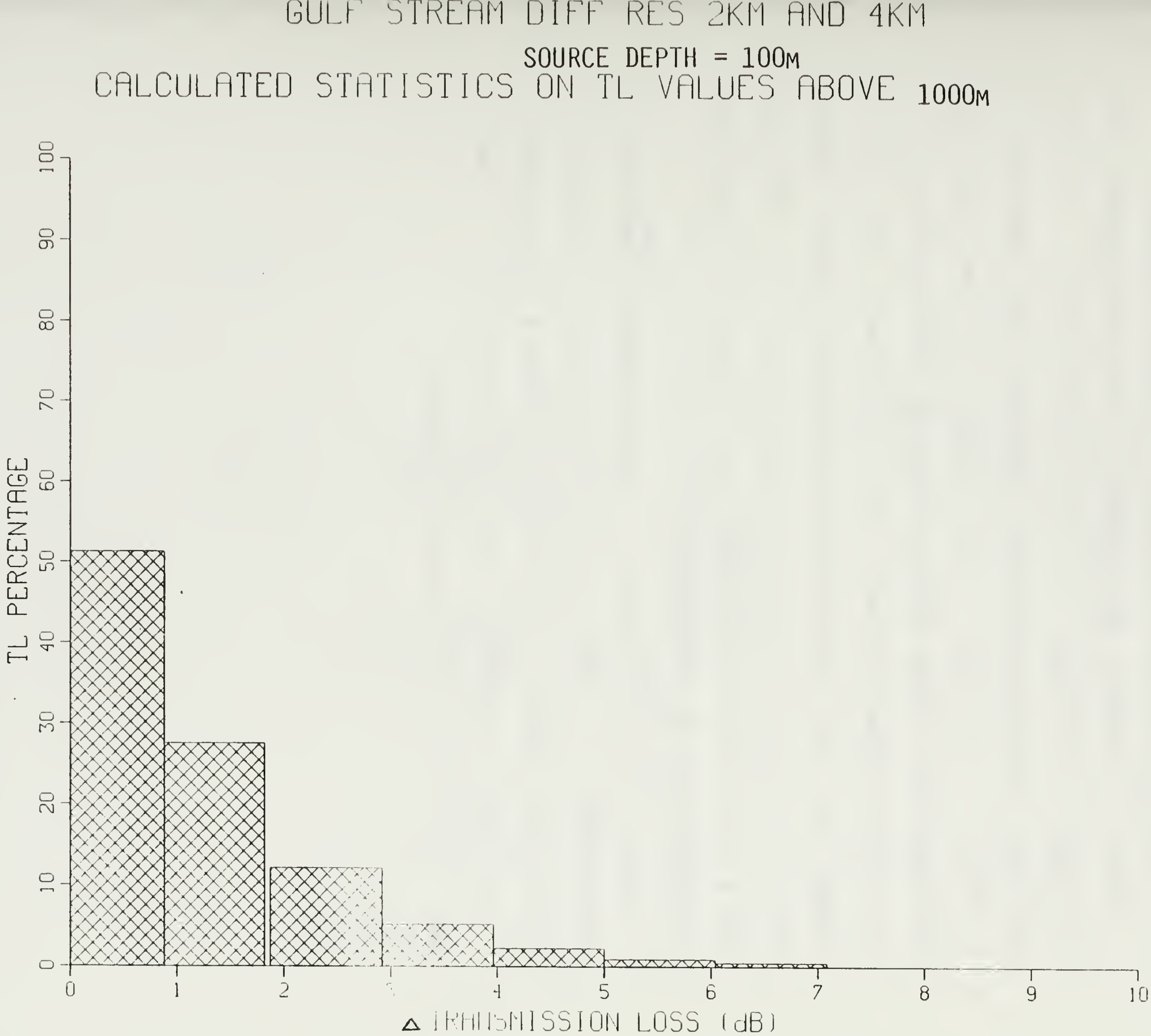


FIG. 10 Histogram Sample of 2-4 km TL Difference Graph

V. RESULTS

Table 3 shows the percent difference values that fall below 2.92 dB for various criteria. Fig. 11 plots those TL percent differences versus range spacings. A cut-off of 2.92 dB was chosen because tactical operations are most affected for TL differences of 3.0 dB or more. These criteria are arbitrary and can be changed to suit the user's requirements. Table 4 shows the TL differences below 2.92 dB for the 100, 500, and 1000 m source depths at each one's respective candidate spacings after TL differencing.

Succinctly, the 100 m source depth requires an approximate horizontal spatial requirement of 8 km; the 500 m source depth, 6 km, and; the 1000 m source depth, 4 km. It is obvious that the horizontal spatial requirements are source depth dependent.

TABLE 3

PERCENT CRITERIA AND RANGE SPACING REQUIRED

Percent	Depth (m)		
	100	500	1000
90%	4 km	n/a	n/a
80	8	4	2
75	8-10	6	4

TABLE 4

RANGE SPACING AND PERCENT FOR ΔTL $<$ 2.92 dB

Range Spacing (km)	Depth (m)		
	100	500	1000
4 km	90.92%		
6	83.09	77.48	72.00
8	76.92	70.74	65.11
10	73.62	67.94	62.16
20		56.50	56.10
25	65.61		
30	65.02		
60	59.41		

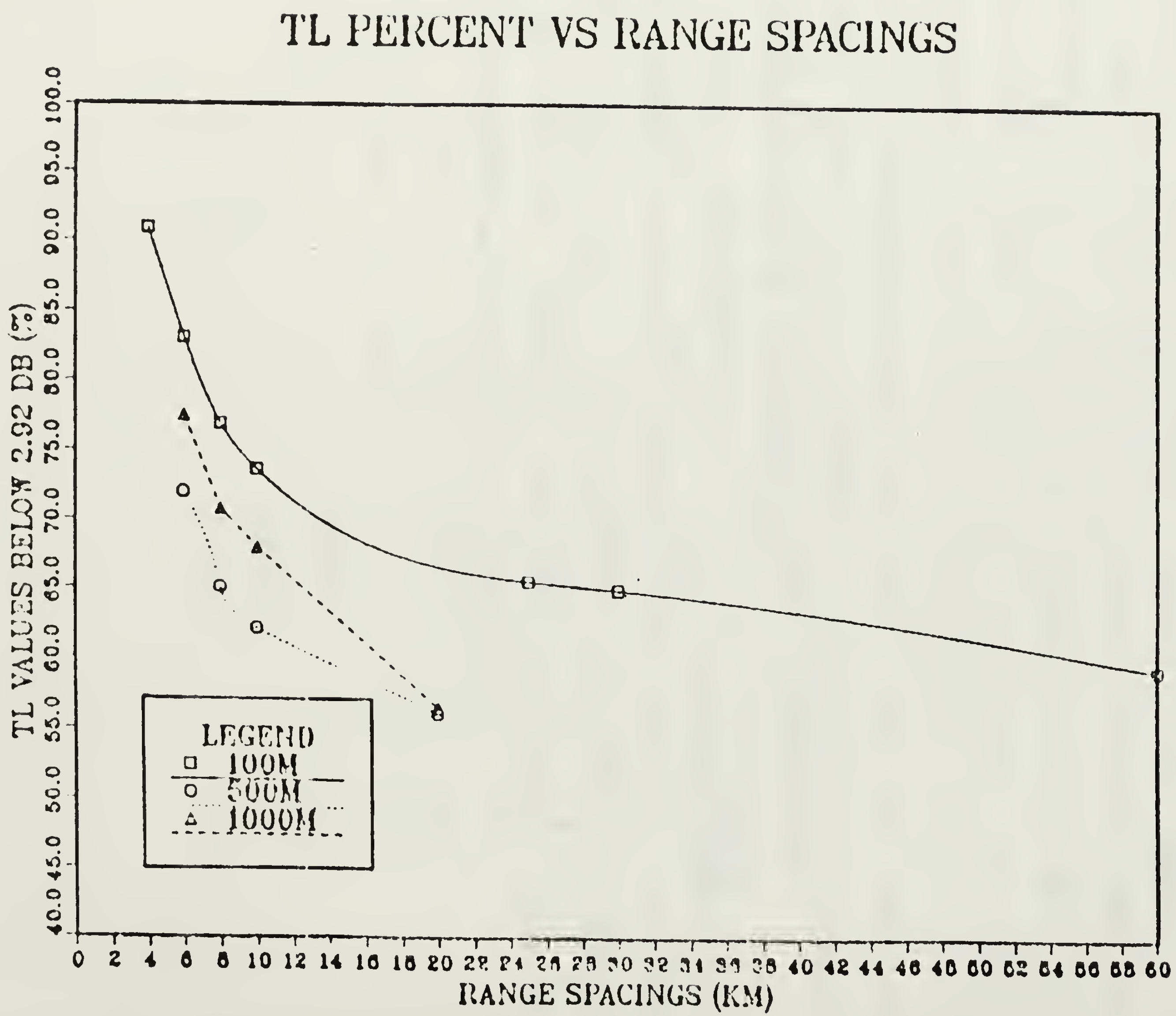


FIG. 11 Percent TL Difference vs Range Spacing

VI. CONCLUSIONS

Other studies have attempted to answer the question this study posed: how does the data base have to be resolved to minimize transmission loss errors for range-dependent models?

Daubin, Tappert, and Nghiem-Phu (Ref. 12) addressed the pertinent issue of the size of a data base— how large a data base is required? In a second study (Ref. 13), they discussed the accuracy of a data base (how accurate must it be? how accurate can it be?)

Unlike the results of this study, Daubin, Tappert, and Nghiem-Phu find that there "was no clearly discernible effect of source depth". This study clearly shows that there is a source depth dependency <u>based upon the transmission loss percent criteria chosen</u>.

Henrick (Ref. 14) argues that using single sound speed profiles for range intervals exceeding about every three km may produce errors and recommends incorporating an interpolation routine. Such a routine was indeed necessary in this study to obtain additional sound speed profiles. This feature may be required in operational range-dependent acoustic propagation loss models.

Other problems regarding the environment needed in an operational range-dependent model need to be addressed. What happens to the horizontal spacing required if the first sound speed profile is moved in relation to the North Wall of the Gulf Stream? Since sound speed is temperature/salinity dependent, what happens to the spacing requirement because of seasonal changes? This study used data obtained in the winter; what if the same procedure were used for data obtained in the summer? Does it make a difference in the spacing required if the acoustic field were travelling from the warm waters of the Sargasso Sea into the cold waters of the Slope Water? What effect do multiple density discontinuities (eddies and fronts) have on the spacing required?

Other questions to be answered involve the resolution of the vertical spatial requirements and the need to resolve specific spacings through a front. The vertical question is more difficult to solve than that of the horizontal spatial needs, but efforts are underway to answer it. For horizontal spacings, maybe an 8 km resolution at 100 m source depth is not required through the entire front. Perhaps, in the specific environment chosen here, 8 km is needed only to define acoustic transmission around the North Wall of the Gulf Stream but a grosser resolution is needed at the South Edge.

The tactical question also must be answered. How are these results (and others revolving around the general environment question) to be used in a tactical environment? in tactical scenario models? This is 1990's technology. However, before that technology can be implemented, the fundamental oceanographic problems must be resolved first.

APPENDIX A

GSFE EXPERIMENTAL DATA

Enclosed are the data from the Gulf Stream Frontal Experiment used in this report.

ORIGINAL BATHYMETRY PROFILE (in nm) TRACK ONE

RANGE	DEPTH
0.0	4836
1.0	4874
2.0	4888
3.0	4884
4.0	4869
5.0	4856
6.0	4850
7.0	4850
8.0	4852
9.0	4855
10.0	4856
11.0	4855
12.0	4854
13.0	4852
14.0	4852
15.0	4852
16.0	4853
17.0	4856
18.0	4860
19.0	4865
20.0	4869
21.0	4874
22.0	4876
23.0	4877
24.0	4878
25.0	4879
26.0	4880
27.0	4882
28.0	4884
29.0	4886
30.0	4888
31.0	4891
32.0	4893
33.0	4896
34.0	4898
35.0	4901
36.0	4904
37.0	4907
38.0	4909
39.0	4911
40.0	4914
41.0	4916
42.0	4918
43.0	4920
44.0	4922
45.0	4924
46.0	4925
47.0	4926
48.0	4928
49.0	4930
50.0	4932
51.0	4935
52.0	4937
53.0	4939
54.0	4940
55.0	4941
56.0	4942
57.0	4944
58.0	4945
59.0	4947
60.0	4949
61.0	4950
62.0	4951
63.0	4952
64.0	4953
65.0	4954
66.0	4955
67.0	4956
68.0	4957
69.0	4958
70.0	4959
71.0	4960
72.0	4961
73.0	4962
74.0	4963

BATHYMETRY PROFILE (in nm) TRACK TWO

RANGE	DEPTH	
0.0	3560	
0.1	3590	*
0.25	3636.75	*
0.40	3682.80	*
0.50	3713.50	*
0.75	3790.20	*
0.90	3836.30	*
1.0	3867	
1.9	4170.3	*
2.0	4204	
2.4	4320	*
2.8	4437.8	*
3.0	4496	
3.4	4566.8	*
3.8	4637.6	*
4.0	4673	
4.1	4678.7	*
4.4	4695.8	*
5.0	4730	
5.8	4713.2	*
6.0	4709	
6.5	4681.5	*
7.0	4654	
7.5	4630.5	*
8.0	4607	
8.8	4587	*
9.0	4582	
10.0	4576	
11.0	4585	
12.0	4608	
13.0	4638	
14.0	4669	
14.4	4680.2	*
15.0	4697	
16.0	4716	
17.0	4727	
18.0	4729	
19.0	4726	
20.0	4718	
21.0	4708	
22.0	4700	
23.0	4694	
23.4	4694	*
24.0	4694	
25.0	4698	
26.0	4705	
27.0	4712	
27.4	4715.2	*
28.0	4720	
29.0	4725	
29.2	4725.6	*
30.0	4728	
31.0	4731	
31.9	4731.9	*
32.0	4732	
33.0	4733	
33.4	4733.4	*
34.0	4734	
35.0	4735	
35.6	4735.6	*
36.0	4736	

(*) indicates ranges and depths interpol
due to the rapid sloping of the shelf

BATHYMETRY PROFILE (in nm) TRACK THREE

RANGE	DEPTH	
0.0	4959	
1.0	4961	
2.0	4963	
3.0	4964	
3.7	4964	*
4.0	4964	
5.0	4964	
6.0	4962	
7.0	4960	
8.0	4957	
9.0	4954	
10.0	4951	
11.0	4950	
12.0	4949	
13.0	4950	
13.7	4951.4	*
14.0	4952	
15.0	4954	
16.0	4957	
17.0	4959	
18.0	4961	
19.0	4963	
20.0	4965	
21.0	4966	
22.0	4967	
23.0	4969	
24.0	4970	
25.0	4972	
26.0	4973	
27.0	4975	
28.0	4976	
29.0	4976	
30.0	4976	
31.0	4976	
32.0	4975	
33.0	4973	
34.0	4972	
35.0	4971	
36.0	4970	
37.0	4929	
37.5	4929	*
38.0	4929	
39.0	4929	

(*) indicates ranges and depths interpolated due to bottom irregularities

BATHYMETRY PROFILE (in nm) TRACK FOUR

RANGE	DEPTH	
0.0	4875	
1.0	4873	
2.0	4872	
3.0	4870	
4.0	4869	
5.0	4868	
6.0	4867	
6.2	4866.6	*
7.0	4865	
8.0	4864	
9.0	4862	
10.0	4860	
11.0	4859	
12.0	4857	
13.0	4856	
14.0	4855	
15.0	4854	
16.0	4853	
17.0	4852	
18.0	4850	
19.0	4848	
20.0	4844	
21.0	4837	
22.0	4826	
23.0	4815	
23.3	4811.7	*
24.0	4804	
25.0	4795	
25.5	4792	*
26.0	4789	
27.0	4786	
28.0	4784	
29.0	4782	
30.0	4780	
31.0	4779	
32.0	4777	
33.0	4775	
34.0	4773	
35.0	4771	
35.2	4770.6	*
36.0	4769	
37.0	4767	
38.0	4766	
39.0	4765	
40.0	4763	
40.8	4762.2	*
41.0	4762	
42.0	4761	
43.0	4760	
43.8	4760	*
44.0	4760	
45.0	4759	
46.0	4759	
46.5	4758	*
47.0	4757	
47.9	4757	*
48.0	4757	
49.0	4755	
49.8	4754.2	*
50.0	4754	
51.0	4752	
51.3	4751.7	*
52.0	4751	
52.7	4750.3	*
53.0	4750	
54.0	4750	
55.0	4750	
55.1	4750	*
56.0	4750	
57.0	4748	
58.0	4746	
58.6	4743.6	*
59.0	4742	
60.0	4737	
61.0	4730	
61.1	4729.4	*
62.0	4724	
63.0	4721	
64.0	4722	
65.0	4731	
65.6	4738.8	*
66.0	4744	
67.0	4759	
68.0	4773	
68.8	4784.2	*
69.0	4787	

(*) indicates ranges and depths interpolated due to bottom irregular

SOUND SPEED PROFILES TRACK ONE (empirical data)

NOTE: Depth is in meters; sound speed is in meters/second

RANGE 0.0 NM

DEPTH	SOUND SPEED
0.0	1515.3
10.0	1514.9
30.0	1516.2
60.0	1518.6
75.0	1514.4
95.0	1509.4
105.0	1509.6
125.0	1505.5
135.0	1503.8
150.0	1503.2
200.0	1498.3
250.0	1491.8
270.0	1488.9
300.0	1487.4
320.0	1486.5
350.0	1482.6
370.0	1483.7
400.0	1483.0
450.0	1481.6
480.0	1481.3
520.0	1481.3
560.0	1480.3
600.0	1480.7
650.0	1480.9
700.0	1481.3
740.0	1481.2
800.0	1481.9
900.0	1483.0
1000.0	1484.2
1100.0	1485.4
1200.0	1486.7
1300.0	1488.0
1400.0	1489.3
1500.0	1490.7
1600.0	1492.1
1800.0	1494.9
2000.0	1497.9
2200.0	1500.5
2500.0	1504.5
3000.0	1511.2
3500.0	1519.0
4000.0	1526.9
4500.0	1535.9
4874.0	1542.6

RANGE 2.8 NM

DEPTH	SOUND SPEED
0.0	1518.0
10.0	1517.9
30.0	1518.3
55.0	1518.8
70.0	1518.2
100.0	1510.2
110.0	1509.4
120.0	1510.2
150.0	1504.0
200.0	1499.4
250.0	1493.5
280.0	1489.6
300.0	1488.5
350.0	1485.4
400.0	1482.6
450.0	1481.3
480.0	1481.2
510.0	1480.6
540.0	1480.7
580.0	1480.2
650.0	1480.8
700.0	1481.0
750.0	1481.5
790.0	1481.8
900.0	1483.0
1000.0	1484.2
1100.0	1485.4
1200.0	1486.7
1300.0	1488.0
1400.0	1489.3
1500.0	1490.7
1600.0	1492.1
1800.0	1494.9
2000.0	1497.9
2200.0	1500.5
2500.0	1504.5
3000.0	1511.2
3500.0	1519.0
4000.0	1526.9
4500.0	1535.9
4885.0	1542.8

RANGE 5.7 NM

DEPTH	SOUND SPEED
0.0	1519.1
10.0	1518.8
25.0	1519.1
50.0	1520.0
75.0	1520.8
105.0	1510.9
120.0	1512.5
130.0	1510.1
135.0	1510.8
155.0	1507.5
165.0	1508.8
200.0	1502.2
250.0	1498.1
300.0	1492.0
350.0	1488.6
380.0	1486.3
410.0	1485.4
430.0	1483.4
480.0	1482.0
510.0	1481.3
540.0	1481.7
570.0	1481.7
600.0	1481.5
650.0	1481.9
700.0	1482.2
750.0	1482.6
790.0	1482.7
900.0	1483.0
1000.0	1484.2
1100.0	1485.4
1200.0	1486.7
1300.0	1488.0
1400.0	1489.3
1500.0	1490.7
1600.0	1492.1
1800.0	1494.9
2000.0	1497.9
2200.0	1500.5
2500.0	1504.5
3000.0	1511.2
3500.0	1519.0
4000.0	1526.9
4500.0	1535.9
4852.0	1542.2

RANGE 8.8 NM

DEPTH	SOUND SPEED
0.0	1519.7
25.0	1520.1
50.0	1520.5
60.0	1520.2
75.0	1520.5
95.0	1521.3
125.0	1513.3
150.0	1509.6
180.0	1507.2
200.0	1505.9
220.0	1505.2
250.0	1500.3
300.0	1495.5
360.0	1490.7
380.0	1490.4
400.0	1488.9
440.0	1485.7
460.0	1485.6
500.0	1483.8
550.0	1482.5
590.0	1482.8
650.0	1482.6
710.0	1482.0
750.0	1482.6
800.0	1483.2
870.0	1483.9
890.0	1483.7
1000.0	1485.0
1100.0	1485.7
1200.0	1487.1
1300.0	1488.2
1400.0	1490.1
1500.0	1491.4
1600.0	1493.0
1800.0	1495.7
2000.0	1498.6
2200.0	1501.3
2500.0	1505.4
3000.0	1512.1
3500.0	1519.2
4000.0	1527.1
4500.0	1535.9
4852.0	1542.2

RANGE 14.4 NM

DEPTH	SOUND SPEED
0.0	1533.7
25.0	1534.0
50.0	1529.1
75.0	1525.2
95.0	1526.1
125.0	1518.4
150.0	1515.1
200.0	1512.6
250.0	1508.7
300.0	1503.5
350.0	1500.6
400.0	1496.8
450.0	1492.2
500.0	1489.8
550.0	1487.4
600.0	1486.0
650.0	1484.8
700.0	1484.1
750.0	1484.0
800.0	1483.9
850.0	1484.5
900.0	1484.8
1000.0	1485.4
1100.0	1486.4
1200.0	1487.1
1300.0	1488.6
1400.0	1489.9
1500.0	1491.3
1600.0	1492.6
1700.0	1494.2
1800.0	1495.6
2000.0	1498.6
2200.0	1501.3
2500.0	1505.4
3000.0	1512.1
3500.0	1519.2
4000.0	1527.1
4500.0	1535.9
4852.0	1542.2

RANGE 15.3 NM

DEPTH	SOUND SPEED
0.0	1534.0
10.0	1434.2
35.0	1534.8
50.0	1530.5
75.0	1525.1
100.0	1526.1
120.0	1524.6
160.0	1516.0
200.0	1513.2
250.0	1509.4
290.0	1508.3
350.0	1501.3
400.0	1498.4
430.0	1495.0
500.0	1490.7
550.0	1488.0
570.0	1487.9
600.0	1486.6
650.0	1485.3
700.0	1484.7
750.0	1484.2
770.0	1484.4
830.0	1484.1
910.0	1484.6
930.0	1484.5
1000.0	1485.3
1100.0	1486.6
1200.0	1487.5
1300.0	1488.6
1400.0	1489.8
1500.0	1491.4
1600.0	1492.5
1700.0	1494.1
1800.0	1495.5
2000.0	1498.6
2200.0	1501.3
2500.0	1505.4
3000.0	1512.1
3500.0	1519.2
4000.0	1527.1
4500.0	1535.9
4852.0	1542.2

RANGE 17.0 NM

DEPTH	SOUND SPEED
0.0	1534.1
20.0	1534.5
40.0	1534.9
65.0	1535.5
80.0	1533.1
100.0	1526.3
125.0	1528.2
150.0	1521.4
200.0	1513.0
250.0	1508.8
300.0	1505.0
330.0	1503.1
340.0	1503.0
400.0	1497.4
420.0	1496.0
440.0	1495.4
500.0	1491.1
550.0	1489.2
600.0	1486.7
620.0	1485.8
640.0	1486.3
700.0	1485.5
730.0	1484.9
750.0	1485.0
820.0	1484.4
850.0	1484.6
900.0	1484.9
1000.0	1485.3
1100.0	1486.6
1200.0	1487.5
1300.0	1488.6
1400.0	1489.8
1500.0	1491.4
1600.0	1492.5
1700.0	1494.1
1800.0	1495.5
2000.0	1498.6
2200.0	1501.3
2500.0	1505.4
3000.0	1512.1
3500.0	1519.2
4000.0	1527.1
4500.0	1535.9
4856.0	1542.3

RANGE 18.8 NM

DEPTH	SOUND SPEED
0.0	1535.3
25.0	1535.8
50.0	1536.0
75.0	1537.2
100.0	1532.6
115.0	1529.0
125.0	1528.9
150.0	1526.3
175.0	1517.6
185.0	1519.8
200.0	1518.5
250.0	1512.1
300.0	1507.2
350.0	1504.7
400.0	1501.9
450.0	1498.5
510.0	1493.8
540.0	1493.0
600.0	1488.5
640.0	1486.6
650.0	1486.8
680.0	1485.4
700.0	1485.4
730.0	1485.0
780.0	1485.5
800.0	1485.5
820.0	1485.7
850.0	1485.2
900.0	1485.6
950.0	1485.6
1000.0	1485.6
1100.0	1486.6
1200.0	1487.8
1300.0	1489.1
1400.0	1490.3
1500.0	1491.8
1600.0	1493.0
1700.0	1494.2
1800.0	1495.6
2000.0	1498.6
2200.0	1501.3
2500.0	1505.4
3000.0	1512.1
3500.0	1519.2
4000.0	1527.1
4500.0	1535.9
4864.0	1542.4

RANGE 20.2 NM

DEPTH	SOUND SPEED
0.0	1534.9
25.0	1535.2
50.0	1535.5
75.0	1536.7
85.0	1536.8
100.0	1536.5
125.0	1529.5
150.0	1527.3
200.0	1520.9
230.0	1514.5
240.0	1516.2
270.0	1514.6
300.0	1510.1
350.0	1506.3
400.0	1503.6
450.0	1501.2
500.0	1497.4
550.0	1493.9
570.0	1493.0
580.0	1492.9
620.0	1489.9
630.0	1489.8
680.0	1486.1
690.0	1486.0
710.0	1484.8
760.0	1485.0
810.0	1484.5
850.0	1485.1
870.0	1485.4
930.0	1485.4
1000.0	1485.9
1100.0	1486.8
1200.0	1487.8
1300.0	1489.1
1400.0	1490.3
1500.0	1491.7
1600.0	1492.9
1700.0	1494.1
1800.0	1495.7
2000.0	1498.6
2200.0	1501.3
2500.0	1505.4
3000.0	1512.1
3500.0	1519.2
4000.0	1527.1
4500.0	1535.9
4870.0	1542.6

RANGE 26.0 NM

DEPTH	SOUND SPEED
0.0	1535.8
25.0	1536.3
50.0	1536.6
75.0	1537.0
105.0	1537.4
125.0	1534.6
150.0	1531.7
200.0	1525.3
230.0	1522.4
250.0	1521.9
300.0	1520.5
350.0	1518.3
380.0	1516.7
440.0	1512.2
460.0	1507.9
500.0	1503.9
550.0	1500.1
600.0	1498.0
650.0	1495.1
700.0	1492.7
800.0	1485.8
870.0	1485.1
900.0	1485.4
1000.0	1485.8
1100.0	1486.7
1200.0	1487.7
1300.0	1488.9
1400.0	1490.4
1500.0	1491.7
1600.0	1493.0
1700.0	1494.5
1800.0	1495.7
2000.0	1498.6
2200.0	1501.3
2500.0	1505.4
3000.0	1512.1
3500.0	1519.2
4000.0	1527.1
4500.0	1535.9
4880.0	1542.7

RANGE 31.3 NM

DEPTH	SOUND SPEED
0.0	1536.0
25.0	1536.3
50.0	1536.5
75.0	1536.8
100.0	1537.0
125.0	1537.9
135.0	1537.2
150.0	1537.7
200.0	1531.1
250.0	1527.7
280.0	1522.7
290.0	1522.5
350.0	1515.9
400.0	1511.8
450.0	1508.6
500.0	1506.5
550.0	1503.1
600.0	1500.1
650.0	1496.8
700.0	1494.4
750.0	1491.7
800.0	1488.4
900.0	1486.1
1000.0	1485.6
1100.0	1486.7
1200.0	1487.7
1300.0	1488.9
1400.0	1490.4
1500.0	1491.7
1600.0	1493.0
1700.0	1494.5
1800.0	1495.7
2000.0	1498.6
2200.0	1501.3
2500.0	1505.4
3000.0	1512.1
3500.0	1519.2
4000.0	1527.1
4500.0	1535.9
4892.0	1543.0

RANGE 36.6 NM

DEPTH	SOUND SPEED
0.0	1536.0
25.0	1536.3
50.0	1536.7
75.0	1536.8
100.0	1537.2
135.0	1537.9
160.0	1536.6
200.0	1532.6
220.0	1531.7
230.0	1531.7
250.0	1529.5
290.0	1525.4
310.0	1524.4
350.0	1520.4
410.0	1516.4
420.0	1516.0
450.0	1513.2
500.0	1510.1
550.0	1508.0
600.0	1505.8
650.0	1503.2
700.0	1501.0
800.0	1496.6
900.0	1492.9
1000.0	1489.8
1050.0	1488.5
1100.0	1489.2
1200.0	1490.0
1300.0	1491.9
1400.0	1492.6
1500.0	1493.8
1600.0	1495.0
1700.0	1496.1
1800.0	1497.6
2000.0	1499.6
2200.0	1502.4
2500.0	1506.4
3000.0	1512.1
3500.0	1519.2
4000.0	1527.1
4500.0	1535.9
4905.0	1543.2

RANGE 42.1 NM

DEPTH	SOUND SPEED
0.0	1536.1
50.0	1537.0
75.0	1537.1
100.0	1537.4
125.0	1537.8
150.0	1534.7
170.0	1534.0
175.0	1534.2
200.0	1532.3
250.0	1528.3
280.0	1526.0
300.0	1525.3
330.0	1523.4
340.0	1523.5
400.0	1520.6
450.0	1517.5
500.0	1514.6
550.0	1510.4
600.0	1508.0
660.0	1503.0
680.0	1502.6
720.0	1499.8
750.0	1498.5
780.0	1496.2
840.0	1494.4
900.0	1493.5
1000.0	1490.7
1100.0	1490.0
1200.0	1490.9
1300.0	1491.9
1400.0	1492.6
1500.0	1493.8
1600.0	1495.0
1700.0	1496.1
1800.0	1497.6
2000.0	1499.6
2200.0	1502.4
2500.0	1506.3
3000.0	1512.1
3500.0	1519.2
4000.0	1527.1
4500.0	1535.9
4918.0	1543.4

RANGE 47.5 NM

DEPTH	SOUND SPEED
0.0	1537.0
25.0	1537.3
50.0	1537.6
80.0	1538.1
95.0	1537.9
110.0	1538.0
125.0	1537.9
150.0	1534.6
165.0	1533.1
185.0	1532.6
200.0	1531.2
250.0	1527.8
270.0	1526.6
300.0	1526.0
350.0	1524.8
420.0	1523.5
520.0	1519.6
550.0	1515.7
600.0	1513.1
670.0	1507.1
750.0	1502.5
780.0	1500.5
810.0	1500.0
850.0	1497.7
900.0	1495.2
950.0	1493.9
1000.0	1492.6
1070.0	1491.7
1100.0	1491.0
1170.0	1490.7
1250.0	1491.8
1280.0	1491.6
1300.0	1491.9
1350.0	1491.9
1400.0	1492.6
1500.0	1493.8
1600.0	1495.0
1700.0	1496.1
1800.0	1497.6
2000.0	1499.6
2200.0	1502.4
2500.0	1506.3
3000.0	1512.1
3500.0	1519.2
4000.0	1527.1
4500.0	1535.9
4927.0	1543.6

RANGE 53.2 NM

DEPTH	SOUND SPEED
0.0	1535.8
5.0	1535.9
35.0	1534.4
50.0	1534.6
75.0	1535.1
100.0	1535.5
130.0	1536.0
140.0	1535.9
150.0	1534.5
195.0	1528.8
200.0	1528.8
230.0	1527.3
270.0	1525.7
320.0	1524.6
400.0	1524.6
470.0	1523.5
550.0	1520.0
600.0	1515.8
630.0	1513.6
670.0	1512.5
700.0	1510.2
750.0	1506.0
800.0	1502.4
850.0	1499.5
900.0	1496.3
1000.0	1492.6
1100.0	1491.0
1200.0	1490.9
1300.0	1491.9
1400.0	1492.6
1500.0	1493.8
1600.0	1495.0
1700.0	1496.1
1800.0	1497.6
2000.0	1499.6
2200.0	1502.4
2500.0	1506.3
3000.0	1512.1
3500.0	1519.2
4000.0	1527.1
4500.0	1535.9
4939.0	1543.8

RANGE 58.7 NM

DEPTH	SOUND SPEED
0.0	1536.5
10.0	1536.6
25.0	1536.0
50.0	1535.1
70.0	1534.6
100.0	1534.9
125.0	1535.0
150.0	1531.3
170.0	1528.8
180.0	1528.7
230.0	1525.8
270.0	1525.2
310.0	1525.2
340.0	1525.0
390.0	1525.2
420.0	1525.2
460.0	1524.9
520.0	1525.3
540.0	1525.2
560.0	1524.6
610.0	1522.9
630.0	1519.4
650.0	1518.8
700.0	1516.2
750.0	1513.0
800.0	1510.4
870.0	1504.9
900.0	1503.9
930.0	1502.1
1000.0	1499.0
1100.0	1496.5
1200.0	1492.9
1300.0	1492.0
1400.0	1492.4
1500.0	1493.4
1600.0	1494.5
1700.0	1495.3
1800.0	1496.5
2000.0	1499.6
2500.0	1506.3
3000.0	1512.1
3500.0	1519.2
4000.0	1527.1
4500.0	1535.9
4945.0	1544.0

RANGE 63.8 NM

DEPTH	SOUND SPEED
0.0	1536.4
25.0	1536.7
50.0	1534.0
65.0	1533.7
90.0	1534.0
115.0	1534.5
150.0	1529.5
175.0	1526.7
200.0	1525.5
250.0	1524.2
340.0	1524.2
400.0	1524.5
460.0	1524.6
490.0	1525.0
530.0	1524.8
580.0	1523.7
590.0	1524.0
600.0	1523.3
650.0	1520.0
700.0	1517.2
750.0	1513.9
800.0	1510.8
850.0	1506.9
900.0	1502.8
1000.0	1498.0
1100.0	1494.8
1200.0	1492.9
1300.0	1492.0
1400.0	1492.4
1500.0	1493.4
1600.0	1494.5
1700.0	1495.3
1800.0	1496.5
2000.0	1499.6
2500.0	1506.3
3000.0	1512.1
3500.0	1519.2
4000.0	1527.1
4500.0	1535.9
4853.0	1544.1

RANGE 69.2 NM

DEPTH	SOUND SPEED
0.0	1536.3
10.0	1536.4
30.0	1535.4
55.0	1534.3
75.0	1534.3
110.0	1534.6
150.0	1528.9
200.0	1525.5
240.0	1524.0
290.0	1523.7
320.0	1523.8
350.0	1523.6
400.0	1523.9
450.0	1524.7
520.0	1525.6
560.0	1525.5
580.0	1525.1
620.0	1525.1
650.0	1525.3
700.0	1521.3
750.0	1517.7
800.0	1514.3
850.0	1509.8
910.0	1506.1
960.0	1502.8
970.0	1502.2
1000.0	1500.5
1100.0	1496.5
1210.0	1492.7
1250.0	1492.1
1280.0	1491.9
1300.0	1492.0
1400.0	1492.4
1500.0	1493.4
1600.0	1494.5
1700.0	1495.3
1800.0	1496.5
2000.0	1499.6
2500.0	1506.3
3000.0	1512.1
3500.0	1519.2
4000.0	1527.1
4500.0	1535.9
4958.0	1544.1

SOUND SPEED PROFILES TRACK TWO

NOTE: Depth is in meters; sound speed is in meters/second

RANGE 0.0 NM

DEPTH	SOUND SPEED
0.0	1502.9
30.0	1520.5
58.0	1521.0
75.0	1517.6
100.0	1513.6
125.0	1509.9
150.0	1507.4
198.0	1502.1
252.0	1498.7
259.0	1498.7
300.0	1495.6
357.0	1491.6
370.0	1491.5
401.0	1489.4
429.0	1487.6
442.0	1487.5
471.0	1485.7
484.0	1485.6
497.0	1484.6
600.0	1482.2
650.0	1482.0
700.0	1482.4
800.0	1482.6
900.0	1483.3
1000.0	1484.1
1100.0	1485.1
1200.0	1486.4
1300.0	1487.9
1400.0	1489.2
1500.0	1490.7
1600.0	1491.9
1800.0	1494.9
2000.0	1497.8
2200.0	1500.4
2500.0	1504.6
3000.0	1511.3
3560.0	1520.0

RANGE 1.9 NM

DEPTH	SOUND SPEED
0.0	1522.3
40.0	1521.4
55.0	1521.4
75.0	1516.8
100.0	1512.4
130.0	1508.6
145.0	1508.4
160.0	1505.5
200.0	1501.8
250.0	1498.5
290.0	1496.5
310.0	1494.5
350.0	1492.0
400.0	1489.6
450.0	1487.0
500.0	1484.8
540.0	1484.6
600.0	1481.9
660.0	1481.5
700.0	1481.9
720.0	1481.7
750.0	1482.0
800.0	1482.6
850.0	1482.8
900.0	1483.3
1000.0	1484.1
1100.0	1485.1
1200.0	1486.4
1300.0	1487.9
1400.0	1489.2
1500.0	1490.7
1600.0	1491.9
1700.0	1493.4
1800.0	1494.8
2000.0	1497.8
2200.0	1500.4
2500.0	1504.6
3000.0	1511.3
3500.0	1519.0
4000.0	1526.9
4170.0	1530.0

RANGE 4.1 NM

DEPTH	SOUND SPEED
0.0	1522.4
30.0	1522.6
60.0	1523.1
75.0	1520.5
105.0	1512.2
110.0	1512.1
135.0	1508.0
155.0	1506.6
165.0	1506.2
205.0	1503.0
240.0	1501.0
270.0	1498.4
300.0	1496.7
350.0	1492.6
400.0	1490.5
450.0	1487.5
500.0	1485.3
520.0	1487.8
550.0	1482.4
600.0	1481.6
640.0	1481.4
700.0	1482.0
750.0	1482.5
790.0	1483.1
830.0	1483.1
900.0	1483.6
950.0	1483.8
1000.0	1484.4
1100.0	1485.0
1200.0	1486.6
1300.0	1488.0
1400.0	1489.3
1500.0	1490.6
1600.0	1491.9
1700.0	1493.4
1800.0	1495.0
2000.0	1497.8
2200.0	1500.4
2500.0	1504.6
3000.0	1511.3
3500.0	1519.0
4000.0	1526.9
4680.0	1539.1

RANGE 5.8 NM

DEPTH	SOUND SPEED
0.0	1527.6
5.0	1527.6
20.0	1522.3
30.0	1523.2
55.0	1523.7
90.0	1514.5
95.0	1514.5
135.0	1507.2
150.0	1506.7
175.0	1505.2
200.0	1503.8
250.0	1500.2
300.0	1496.8
340.0	1493.0
400.0	1490.9
440.0	1488.2
460.0	1487.2
500.0	1486.0
530.0	1485.4
570.0	1483.2
600.0	1482.8
640.0	1482.7
670.0	1482.5
700.0	1482.6
750.0	1482.8
800.0	1483.4
850.0	1483.8
900.0	1484.0
950.0	1484.3
1000.0	1484.4
1100.0	1485.0
1200.0	1486.6
1300.0	1488.0
1400.0	1489.3
1500.0	1490.6
1600.0	1491.9
1700.0	1493.4
1800.0	1495.0
2000.0	1497.8
2200.0	1500.4
2500.0	1504.6
3000.0	1511.3
3500.0	1519.0
4000.0	1526.9
4713.0	1539.7

RANGE 8.8 NM

DEPTH	SOUND SPEED
0.0	1529.0
15.0	1528.8
20.0	1530.0
35.0	1523.8
40.0	1524.3
50.0	1523.3
65.0	1523.5
80.0	1521.3
100.0	1511.5
115.0	1508.9
125.0	1508.8
150.0	1505.4
175.0	1503.5
210.0	1500.5
220.0	1500.2
250.0	1498.2
300.0	1495.6
350.0	1491.9
400.0	1488.4
450.0	1486.1
500.0	1483.4
550.0	1482.3
570.0	1482.5
610.0	1482.1
630.0	1482.2
660.0	1481.9
700.0	1482.0
750.0	1482.4
800.0	1482.6
900.0	1483.1
1000.0	1484.3
1100.0	1485.4
1200.0	1486.4
1300.0	1487.5
1400.0	1488.9
1500.0	1490.5
1600.0	1491.2
1800.0	1494.5
2000.0	1497.8
2200.0	1500.4
2500.0	1504.6
3000.0	1511.3
3500.0	1519.0
4000.0	1526.9
4587.0	1537.5

RANGE 14.4 NM

DEPTH	SOUND SPEED
0.0	1529.7
10.0	1529.4
40.0	1522.8
55.0	1523.9
65.0	1523.0
80.0	1524.0
100.0	1514.4
125.0	1509.8
135.0	1509.6
150.0	1507.6
175.0	1504.8
200.0	1503.2
250.0	1499.6
290.0	1496.2
300.0	1496.2
350.0	1493.4
380.0	1491.5
420.0	1490.5
460.0	1488.1
470.0	1488.1
500.0	1486.2
550.0	1484.5
580.0	1482.9
630.0	1482.4
680.0	1482.5
740.0	1482.1
780.0	1482.3
810.0	1482.2
850.0	1482.4
940.0	1483.9
1000.0	1484.3
1100.0	1485.4
1200.0	1486.4
1300.0	1487.5
1400.0	1488.9
1500.0	1490.5
1600.0	1491.2
1700.0	1492.9
1800.0	1494.5
2000.0	1497.8
2200.0	1500.4
2500.0	1504.6
3000.0	1511.3
3500.0	1519.0
4000.0	1526.9
4681.0	1539.2

RANGE 19.0 NM

DEPTH	SOUND SPEED
0.0	1533.0
20.0	1533.5
40.0	1527.3
60.0	1524.7
75.0	1526.2
100.0	1521.8
125.0	1517.3
140.0	1515.2
145.0	1515.9
175.0	1512.5
200.0	1509.4
250.0	1503.6
300.0	1500.0
350.0	1495.4
390.0	1491.8
400.0	1491.6
450.0	1489.1
470.0	1488.1
480.0	1488.2
550.0	1484.9
600.0	1484.4
650.0	1483.9
700.0	1482.4
750.0	1481.6
800.0	1482.0
900.0	1483.4
1000.0	1484.4
1100.0	1485.4
1200.0	1486.9
1300.0	1488.1
1400.0	1489.3
1500.0	1490.6
1600.0	1491.8
1800.0	1494.8
2000.0	1497.8
2200.0	1500.4
2500.0	1504.6
3000.0	1511.3
3500.0	1519.0
4000.0	1526.9
4726.0	1540.0

RANGE 23.4 NM

DEPTH	SOUND SPEED
0.0	1530.2
25.0	1530.4
50.0	1528.3
70.0	1523.4
80.0	1527.2
100.0	1523.4
110.0	1518.9
115.0	1519.6
140.0	1515.9
160.0	1511.2
200.0	1507.7
250.0	1504.8
300.0	1501.1
330.0	1498.6
340.0	1498.4
400.0	1495.2
430.0	1493.1
450.0	1492.7
500.0	1489.1
540.0	1486.0
560.0	1485.7
620.0	1483.8
650.0	1484.2
690.0	1482.3
720.0	1481.8
760.0	1481.6
800.0	1482.0
860.0	1483.1
880.0	1483.0
950.0	1483.8
990.0	1484.4
1020.0	1484.2
1100.0	1485.4
1200.0	1486.9
1300.0	1488.1
1400.0	1489.3
1500.0	1490.6
1600.0	1491.8
1700.0	1493.5
1800.0	1494.8
2000.0	1497.8
2200.0	1500.4
2500.0	1504.6
3000.0	1511.3
3500.0	1519.0
4000.0	1526.9
4694.0	1539.4

RANGE 27.4 NM

DEPTH	SOUND SPEED
0.0	1533.5
25.0	1534.0
50.0	1534.6
75.0	1527.9
105.0	1520.4
115.0	1524.0
125.0	1521.5
160.0	1515.0
195.0	1508.4
200.0	1508.4
220.0	1506.4
230.0	1506.3
270.0	1503.0
320.0	1500.0
330.0	1499.8
360.0	1496.7
370.0	1496.4
400.0	1494.2
450.0	1492.0
500.0	1489.6
550.0	1486.7
600.0	1485.0
650.0	1484.0
690.0	1482.3
710.0	1482.5
740.0	1482.2
800.0	1482.5
900.0	1483.4
1000.0	1484.4
1100.0	1485.4
1200.0	1486.9
1300.0	1488.1
1400.0	1489.3
1500.0	1490.6
1600.0	1491.8
1800.0	1494.8
2000.0	1497.8
2200.0	1500.4
2500.0	1504.6
3000.0	1511.3
3500.0	1519.0
4000.0	1526.9
4715.0	1539.8

RANGE 29.2 NM

DEPTH	SOUND SPEED
0.0	1533.7
30.0	1534.4
60.0	1535.1
70.0	1535.0
90.0	1523.2
100.0	1521.5
110.0	1520.3
115.0	1520.6
120.0	1519.7
125.0	1522.2
150.0	1518.3
180.0	1512.1
195.0	1512.8
240.0	1505.5
250.0	1505.3
300.0	1502.6
340.0	1499.1
370.0	1498.4
400.0	1496.0
450.0	1493.0
500.0	1490.4
550.0	1488.2
590.0	1486.4
600.0	1486.5
650.0	1485.1
690.0	1483.6
710.0	1484.1
750.0	1483.3
800.0	1483.0
900.0	1484.1
1000.0	1485.6
1100.0	1486.7
1200.0	1487.6
1300.0	1488.9
1400.0	1490.0
1500.0	1491.2
1600.0	1492.6
1800.0	1495.5
2000.0	1498.6
2200.0	1501.3
2500.0	1505.4
3000.0	1512.1
3500.0	1519.2
4000.0	1527.1
4726.0	1540.0

RANGE 31.9 NM

DEPTH	SOUND SPEED
0.0	1534.5
25.0	1534.8
50.0	1535.1
90.0	1536.3
125.0	1528.1
150.0	1523.5
175.0	1519.4
200.0	1515.3
250.0	1511.4
270.0	1507.6
300.0	1506.1
350.0	1501.6
400.0	1498.2
440.0	1495.3
450.0	1495.3
500.0	1492.9
540.0	1490.7
600.0	1488.3
650.0	1486.3
700.0	1484.7
760.0	1483.3
780.0	1483.4
800.0	1483.0
850.0	1483.4
900.0	1484.1
950.0	1484.6
1000.0	1485.6
1100.0	1486.7
1200.0	1487.6
1300.0	1488.9
1400.0	1490.0
1500.0	1491.2
1600.0	1492.9
1700.0	1493.9
1800.0	1495.5
2000.0	1498.6
2200.0	1501.3
2500.0	1505.4
3000.0	1512.1
3500.0	1519.2
4000.0	1527.1
4732.0	1540.1

RANGE 33.4 NM

DEPTH	SOUND SPEED
0.0	1534.3
25.0	1535.2
50.0	1535.5
75.0	1536.8
95.0	1537.1
125.0	1530.4
140.0	1527.4
145.0	1527.4
170.0	1524.2
175.0	1524.0
200.0	1520.3
250.0	1514.6
300.0	1510.8
310.0	1510.5
350.0	1506.0
400.0	1501.1
450.0	1497.3
470.0	1495.7
490.0	1495.5
550.0	1492.4
590.0	1490.3
610.0	1490.1
650.0	1488.5
700.0	1486.9
750.0	1485.1
800.0	1484.5
850.0	1484.2
900.0	1485.0
1000.0	1485.8
1100.0	1487.2
1200.0	1488.0
1300.0	1489.3
1400.0	1490.5
1500.0	1491.9
1600.0	1493.4
1800.0	1496.4
2000.0	1498.6
2200.0	1501.3
2500.0	1505.4
3000.0	1512.1
3500.0	1519.2
4000.0	1527.1
4733.0	1540.1

RANGE 35.6 NM

DEPTH	SOUND SPEED
0.0	1534.7
25.0	1535.2
50.0	1535.5
75.0	1535.8
95.0	1536.1
125.0	1531.6
150.0	1529.0
175.0	1527.0
200.0	1524.1
250.0	1518.4
300.0	1513.7
330.0	1511.8
340.0	1511.6
400.0	1505.0
450.0	1499.6
500.0	1495.6
550.0	1493.2
600.0	1490.8
650.0	1489.0
700.0	1487.2
750.0	1485.8
800.0	1484.5
830.0	1484.1
880.0	1485.1
900.0	1485.0
950.0	1485.2
1000.0	1485.8
1100.0	1487.2
1200.0	1488.0
1300.0	1489.3
1400.0	1490.5
1500.0	1491.9
1600.0	1493.4
1800.0	1496.4
2000.0	1498.6
2200.0	1501.3
2500.0	1505.4
3000.0	1512.1
3500.0	1519.2
4000.0	1527.1
4736.0	1540.1

SOUND SPEED PROFILES TRACK THREE

NOTE: Depth is in meters; sound speed is in meters/second

RANGE 0.0 NM

DEPTH	SOUND SPEED
0.0	1533.8
25.0	1534.0
50.0	1534.4
70.0	1534.7
85.0	1535.0
100.0	1534.4
125.0	1534.1
150.0	1530.9
175.0	1528.0
200.0	1526.9
250.0	1524.8
290.0	1524.6
350.0	1524.5
400.0	1524.7
450.0	1524.8
470.0	1524.7
490.0	1524.8
550.0	1523.4
600.0	1521.6
650.0	1519.7
700.0	1517.5
750.0	1514.5
800.0	1511.2
860.0	1506.3
870.0	1506.1
900.0	1504.8
1000.0	1499.9
1100.0	1495.6
1200.0	1493.6
1230.0	1493.0
1300.0	1493.1
1400.0	1493.4
1500.0	1494.4
1600.0	1494.5
1800.0	1496.7
2000.0	1499.6
2200.0	1502.4
2500.0	1506.4
3000.0	1512.6
3500.0	1519.6
4000.0	1527.3
4500.0	1535.9
4959.0	1544.2

RANGE 2.0 NM

DEPTH	SOUND SPEED
0.0	1533.6
25.0	1533.9
50.0	1534.2
65.0	1534.4
75.0	1534.0
100.0	1533.8
120.0	1533.4
150.0	1530.2
175.0	1527.5
200.0	1525.7
230.0	1524.8
290.0	1524.6
350.0	1524.7
430.0	1524.9
470.0	1524.7
500.0	1524.8
550.0	1523.9
600.0	1522.3
650.0	1520.6
700.0	1518.3
750.0	1515.5
800.0	1512.7
850.0	1509.0
900.0	1504.7
950.0	1502.5
1000.0	1499.9
1050.0	1498.0
1100.0	1495.6
1150.0	1494.8
1200.0	1493.6
1230.0	1493.0
1260.0	1493.4
1300.0	1493.1
1400.0	1493.4
1500.0	1494.4
1600.0	1494.5
1800.0	1496.7
2000.0	1499.7
2200.0	1502.4
2500.0	1506.4
3000.0	1512.6
3500.0	1519.6
4000.0	1527.3
4500.0	1535.9
4963.0	1544.2

RANGE 3.7 NM

DEPTH	SOUND SPEED
0.0	1533.7
25.0	1534.1
50.0	1534.3
75.0	1534.8
90.0	1533.9
105.0	1533.8
120.0	1534.0
140.0	1531.0
160.0	1528.6
165.0	1528.6
200.0	1526.0
250.0	1525.0
300.0	1524.5
350.0	1524.7
410.0	1525.1
430.0	1525.0
470.0	1525.0
500.0	1524.7
550.0	1524.2
600.0	1522.6
650.0	1520.4
700.0	1518.3
750.0	1516.0
800.0	1513.3
850.0	1509.6
900.0	1505.4
910.0	1505.1
960.0	1502.3
970.0	1502.2
1000.0	1500.5
1050.0	1498.2
1100.0	1496.2
1150.0	1495.1
1180.0	1494.4
1200.0	1494.4
1240.0	1493.2
1260.0	1493.3
1300.0	1493.0
1330.0	1492.9
1400.0	1493.6
1500.0	1494.1
1600.0	1494.6
1800.0	1496.7
2000.0	1499.6
2200.0	1502.4
2500.0	1506.4
3000.0	1512.6
3500.0	1519.6
4000.0	1527.3
4500.0	1535.9
4964.0	1544.2

RANGE 13.7 NM

DEPTH	SOUND SPEED
0.0	1534.0
25.0	1534.4
50.0	1534.7
80.0	1535.2
90.0	1534.6
105.0	1534.5
115.0	1534.0
125.0	1533.0
145.0	1529.8
150.0	1529.6
175.0	1527.3
200.0	1525.8
230.0	1524.9
270.0	1524.9
300.0	1525.2
350.0	1525.5
420.0	1525.7
450.0	1525.6
480.0	1525.7
510.0	1525.5
550.0	1525.4
600.0	1524.1
650.0	1521.4
700.0	1519.6
750.0	1517.4
800.0	1514.3
850.0	1511.1
900.0	1507.6
950.0	1504.7
1000.0	1502.7
1100.0	1496.2
1200.0	1494.4
1250.0	1493.3
1300.0	1493.0
1400.0	1493.6
1500.0	1494.1
1600.0	1494.6
1800.0	1496.7
2000.0	1499.6
2200.0	1502.4
2500.0	1506.4
3000.0	1512.6
3500.0	1519.6
4000.0	1527.3
4500.0	1535.9
4952.0	1544.0

RANGE 20.0 NM

DEPTH	SOUND SPEED
0.0	1533.7
25.0	1534.0
50.0	1534.3
80.0	1534.6
95.0	1533.6
105.0	1533.6
110.0	1533.2
120.0	1533.3
150.0	1528.8
155.0	1529.1
175.0	1526.4
200.0	1524.8
230.0	1524.0
260.0	1524.1
300.0	1524.2
350.0	1524.4
400.0	1524.8
450.0	1524.9
500.0	1524.8
550.0	1524.6
600.0	1523.2
650.0	1520.2
680.0	1519.7
700.0	1519.7
750.0	1516.6
800.0	1513.2
850.0	1508.9
880.0	1508.1
950.0	1504.7
1000.0	1500.5
1100.0	1496.2
1200.0	1494.4
1250.0	1493.3
1300.0	1493.0
1400.0	1493.6
1500.0	1494.1
1600.0	1494.6
1800.0	1496.7
2000.0	1499.6
2200.0	1502.4
2500.0	1506.4
3000.0	1512.6
3500.0	1519.6
4000.0	1527.3
4500.0	1535.9
4965.0	1544.2

RANGE 37.5 NM

DEPTH	SOUND SPEED
0.0	1534.2
25.0	1534.5
50.0	1534.7
75.0	1534.8
100.0	1535.0
125.0	1535.6
150.0	1531.6
175.0	1529.5
200.0	1527.9
230.0	1526.3
270.0	1525.3
310.0	1525.4
330.0	1525.3
390.0	1525.7
450.0	1525.4
500.0	1525.2
550.0	1525.0
600.0	1524.1
650.0	1522.5
700.0	1520.2
750.0	1517.4
800.0	1514.9
850.0	1511.7
900.0	1507.9
950.0	1505.4
1000.0	1502.6
1050.0	1499.8
1100.0	1497.1
1150.0	1495.1
1180.0	1494.1
1210.0	1493.6
1270.0	1494.1
1290.0	1493.5
1320.0	1493.8
1400.0	1494.2
1500.0	1495.1
1600.0	1496.2
1800.0	1497.7
2000.0	1499.6
2200.0	1502.4
2500.0	1506.4
3000.0	1512.6
3500.0	1519.6
4000.0	1527.3
4500.0	1535.9
4929.0	1543.6

SOUND SPEED PROFILES TRACK FOUR

NOTE: Depth is in meters; sound speed is in meters/second

RANGE 0.0 NM

DEPTH	SOUND SPEED
0.0	1532.8
25.0	1533.3
50.0	1533.7
65.0	1533.9
75.0	1533.3
100.0	1530.6
125.0	1528.0
150.0	1525.8
175.0	1525.0
200.0	1524.2
230.0	1523.8
270.0	1523.7
300.0	1523.8
350.0	1524.0
400.0	1524.5
460.0	1524.8
500.0	1524.5
550.0	1523.9
600.0	1522.2
650.0	1519.9
700.0	1516.0
730.0	1512.0
750.0	1511.4
810.0	1506.2
850.0	1505.4
900.0	1503.7
1000.0	1498.3
1100.0	1494.2
1200.0	1492.4
1250.0	1492.2
1300.0	1492.4
1400.0	1492.8
1500.0	1493.8
1600.0	1494.8
1800.0	1496.9
2000.0	1499.6
2200.0	1502.4
2500.0	1506.4
3000.0	1512.6
3500.0	1519.6
4000.0	1527.3
4500.0	1535.9
4875.0	1542.6

RANGE 6.2 NM

DEPTH	SOUND SPEED
0.0	1534.0
25.0	1534.6
35.0	1534.8
40.0	1534.3
60.0	1534.6
75.0	1534.7
100.0	1532.5
125.0	1528.3
150.0	1526.9
175.0	1525.2
200.0	1524.5
240.0	1524.2
300.0	1524.4
350.0	1524.6
400.0	1524.8
440.0	1524.8
500.0	1524.3
550.0	1522.6
600.0	1519.8
650.0	1517.8
700.0	1514.9
750.0	1510.0
800.0	1507.2
900.0	1503.7
1000.0	1498.3
1100.0	1494.2
1200.0	1492.4
1250.0	1492.2
1300.0	1492.4
1400.0	1492.8
1500.0	1493.8
1600.0	1494.8
1800.0	1496.9
2000.0	1499.6
2200.0	1502.4
2500.0	1506.4
3000.0	1512.6
3500.0	1519.6
4000.0	1527.3
4500.0	1535.9
4867.0	1542.5

RANGE 17.0 NM

DEPTH	SOUND SPEED
0.0	1533.8
35.0	1534.4
50.0	1533.8
75.0	1534.1
100.0	1530.2
125.0	1527.9
130.0	1527.8
150.0	1526.6
180.0	1524.5
210.0	1524.0
250.0	1523.7
300.0	1523.7
350.0	1523.8
380.0	1523.9
410.0	1523.7
440.0	1523.9
490.0	1523.7
550.0	1521.7
600.0	1518.3
650.0	1515.4
700.0	1514.1
750.0	1510.1
800.0	1505.0
850.0	1502.0
900.0	1499.1
950.0	1496.2
1000.0	1493.5
1100.0	1491.0
1200.0	1490.5
1300.0	1491.0
1400.0	1492.4
1500.0	1493.8
1600.0	1494.8
1800.0	1496.9
2000.0	1499.6
2200.0	1502.4
2500.0	1506.4
3000.0	1512.6
3500.0	1519.6
4000.0	1527.3
4500.0	1535.9
4852.0	1542.2

RANGE 23.3 NM

DEPTH	SOUND SPEED
0.0	1533.1
25.0	1533.3
50.0	1533.7
75.0	1531.7
100.0	1529.5
125.0	1526.4
150.0	1524.7
175.0	1523.8
200.0	1523.5
250.0	1523.6
300.0	1523.3
400.0	1523.3
450.0	1523.1
500.0	1522.3
550.0	1520.8
600.0	1516.1
650.0	1512.5
700.0	1509.1
750.0	1505.7
800.0	1501.2
820.0	1499.6
840.0	1499.0
900.0	1494.3
950.0	1492.0
1000.0	1489.9
1050.0	1489.7
1100.0	1489.5
1150.0	1489.4
1200.0	1489.8
1250.0	1490.3
1300.0	1491.1
1400.0	1492.3
1500.0	1493.8
1600.0	1494.8
1800.0	1496.9
2000.0	1499.6
2200.0	1502.4
2500.0	1506.4
3000.0	1512.6
3500.0	1519.6
4000.0	1527.3
4500.0	1535.9
4812.0	1541.5

RANGE 25.5 NM

DEPTH	SOUND SPEED
0.0	1532.7
25.0	1533.3
50.0	1533.7
65.0	1533.9
75.0	1532.4
100.0	1528.6
115.0	1527.0
120.0	1527.1
150.0	1525.2
175.0	1524.1
200.0	1523.6
230.0	1523.3
260.0	1523.4
310.0	1523.3
340.0	1523.1
390.0	1523.3
450.0	1522.4
500.0	1520.9
550.0	1518.2
600.0	1513.7
660.0	1506.8
680.0	1506.0
750.0	1499.9
800.0	1496.8
850.0	1493.9
900.0	1491.5
1000.0	1488.7
1100.0	1488.3
1200.0	1489.2
1300.0	1490.4
1400.0	1490.8
1500.0	1492.3
1600.0	1493.2
1800.0	1496.0
2000.0	1499.6
2200.0	1502.4
2500.0	1506.4
3000.0	1512.6
3500.0	1519.6
4000.0	1527.3
4500.0	1535.9
4792.0	1541.2

RANGE 32.0 NM

DEPTH	SOUND SPEED
0.0	1532.9
25.0	1533.2
50.0	1533.4
75.0	1533.7
90.0	1529.1
100.0	1529.1
125.0	1526.5
150.0	1524.6
175.0	1523.8
200.0	1523.3
250.0	1523.2
300.0	1523.4
350.0	1523.1
400.0	1522.3
440.0	1520.9
460.0	1520.8
500.0	1518.7
550.0	1513.8
600.0	1509.0
650.0	1503.3
700.0	1499.7
750.0	1496.7
800.0	1493.6
850.0	1491.3
900.0	1489.7
950.0	1488.7
990.0	1488.8
1030.0	1488.1
1070.0	1488.3
1100.0	1488.3
1150.0	1488.9
1220.0	1489.4
1240.0	1489.2
1300.0	1490.4
1360.0	1490.5
1380.0	1490.4
1400.0	1490.8
1500.0	1492.3
1600.0	1493.2
1800.0	1496.0
2000.0	1499.9
2200.0	1502.4
2500.0	1506.4
3000.0	1512.6
3500.0	1519.6
4000.0	1527.3
4500.0	1535.9
4777.0	1540.9

RANGE 35.2 NM

DEPTH	SOUND SPEED
0.0	1532.8
35.0	1533.2
65.0	1533.6
74.0	1532.2
99.0	1528.6
123.0	1526.3
148.0	1524.5
168.0	1523.5
201.0	1523.0
245.0	1522.8
301.0	1522.5
353.0	1522.2
398.0	1521.1
450.0	1519.2
497.0	1513.8
520.0	1510.6
535.0	1510.0
559.0	1506.6
599.0	1501.8
653.0	1498.3
690.0	1495.5
703.0	1495.0
750.0	1492.1
798.0	1489.8
832.0	1488.8
900.0	1487.0
950.0	1486.8
1000.0	1487.1
1100.0	1488.0
1200.0	1488.6
1300.0	1489.6
1400.0	1490.4
1500.0	1492.0
1600.0	1493.1
1800.0	1496.4
2000.0	1499.6
2200.0	1502.4
2500.0	1506.4
3000.0	1512.6
3500.0	1519.6
4000.0	1527.3
4500.0	1535.9
4771.0	1540.8

RANGE 40.8 NM

DEPTH	SOUND SPEED
0.0	1534.8
25.0	1535.2
50.0	1535.6
65.0	1535.5
100.0	1531.5
125.0	1525.0
150.0	1523.3
200.0	1522.2
250.0	1521.6
300.0	1521.4
350.0	1520.2
400.0	1516.8
450.0	1510.9
500.0	1505.0
600.0	1495.8
610.0	1495.6
640.0	1494.4
700.0	1491.0
770.0	1488.4
820.0	1488.1
860.0	1487.1
900.0	1486.5
930.0	1486.9
960.0	1486.8
1000.0	1487.1
1050.0	1487.3
1100.0	1488.0
1130.0	1488.5
1150.0	1488.2
1200.0	1488.6
1300.0	1489.6
1400.0	1490.4
1500.0	1492.0
1600.0	1493.1
1800.0	1496.4
2000.0	1499.6
2200.0	1502.4
2500.0	1506.4
3000.0	1512.6
3500.0	1519.6
4000.0	1527.3
4500.0	1535.9
4761.0	1540.6

RANGE 43.8 NM

DEPTH	SOUND SPEED
0.0	1534.8
25.0	1535.3
50.0	1535.8
85.0	1536.5
100.0	1532.8
125.0	1529.0
150.0	1526.2
175.0	1523.9
190.0	1522.5
200.0	1522.1
250.0	1520.6
260.0	1520.4
280.0	1520.4
300.0	1519.2
350.0	1515.2
380.0	1509.1
420.0	1505.9
450.0	1503.1
500.0	1498.4
550.0	1493.7
580.0	1492.9
600.0	1491.4
650.0	1488.4
680.0	1487.2
710.0	1487.4
730.0	1487.1
800.0	1486.0
850.0	1485.5
900.0	1486.2
1000.0	1487.1
1100.0	1488.0
1200.0	1488.6
1300.0	1489.6
1400.0	1490.4
1500.0	1492.0
1600.0	1493.1
1800.0	1496.4
2000.0	1499.6
2200.0	1502.4
2500.0	1506.4
3000.0	1512.6
3500.0	1519.6
4000.0	1527.3
4500.0	1535.9
4761.0	1540.6

RANGE 46.5 NM

DEPTH	SOUND SPEED
0.0	1534.2
25.0	1534.6
50.0	1535.0
75.0	1536.6
85.0	1536.7
95.0	1533.2
100.0	1533.1
105.0	1532.6
110.0	1532.4
120.0	1529.5
125.0	1529.5
150.0	1527.5
175.0	1524.2
200.0	1521.4
240.0	1518.1
280.0	1510.3
300.0	1508.8
350.0	1505.6
400.0	1501.4
450.0	1497.8
500.0	1494.2
530.0	1492.7
540.0	1492.8
600.0	1489.4
650.0	1486.7
700.0	1486.1
750.0	1485.7
800.0	1484.8
900.0	1485.4
1000.0	1486.2
1100.0	1486.5
1200.0	1487.8
1300.0	1488.7
1400.0	1489.7
1500.0	1491.2
1600.0	1492.6
1800.0	1495.7
2000.0	1499.6
2200.0	1502.4
2500.0	1506.4
3000.0	1512.6
3500.0	1519.6
4000.0	1527.3
4500.0	1535.9
4758.0	1540.5

RANGE 47.9 NM

DEPTH	SOUND SPEED
0.0	1533.7
25.0	1534.3
50.0	1535.1
75.0	1535.8
100.0	1531.6
125.0	1529.1
150.0	1525.6
175.0	1522.7
200.0	1517.7
250.0	1509.6
260.0	1509.6
300.0	1506.4
340.0	1503.9
350.0	1503.6
400.0	1499.9
450.0	1495.9
510.0	1493.4
530.0	1493.5
550.0	1491.6
600.0	1490.0
650.0	1488.1
700.0	1486.9
750.0	1485.4
800.0	1484.9
820.0	1484.8
850.0	1484.9
900.0	1485.4
970.0	1486.3
990.0	1486.2
1040.0	1486.3
1070.0	1486.2
1100.0	1486.5
1200.0	1487.8
1300.0	1488.7
1400.0	1489.7
1500.0	1491.2
1600.0	1492.6
1800.0	1495.7
2000.0	1498.2
2200.0	1501.3
2500.0	1505.4
3000.0	1512.1
3500.0	1519.2
4000.0	1527.1
4500.0	1535.9
4757.0	1540.5

RANGE 49.8 NM

DEPTH	SOUND SPEED
0.0	1533.7
20.0	1534.0
45.0	1534.9
70.0	1531.5
85.0	1534.2
100.0	1531.4
125.0	1526.0
150.0	1519.3
160.0	1520.8
180.0	1511.9
195.0	1510.8
200.0	1510.4
250.0	1507.0
300.0	1503.7
340.0	1501.2
350.0	1501.0
400.0	1498.0
470.0	1493.6
490.0	1493.8
550.0	1490.2
560.0	1490.2
620.0	1487.4
640.0	1487.3
690.0	1485.1
720.0	1484.9
760.0	1484.3
780.0	1484.4
800.0	1484.2
850.0	1484.9
900.0	1485.2
920.0	1485.1
970.0	1485.2
1000.0	1485.8
1100.0	1486.1
1200.0	1486.9
1300.0	1488.1
1400.0	1489.2
1500.0	1490.5
1600.0	1492.3
1800.0	1495.1
2000.0	1498.0
2200.0	1501.3
2500.0	1505.4
3000.0	1512.1
3500.0	1519.2
4000.0	1527.1
4500.0	1535.9
4754.0	1540.5

RANGE 51.3 NM

DEPTH	SOUND SPEED
0.0	1532.5
25.0	1533.0
40.0	1531.9
55.0	1531.0
65.0	1530.9
85.0	1532.9
100.0	1524.7
115.0	1522.0
125.0	1525.3
150.0	1515.3
175.0	1509.7
185.0	1508.5
200.0	1509.1
250.0	1505.4
300.0	1502.3
350.0	1498.7
400.0	1495.4
440.0	1493.8
450.0	1493.8
510.0	1490.0
520.0	1490.2
560.0	1487.6
600.0	1487.2
650.0	1485.6
700.0	1484.5
740.0	1483.9
770.0	1484.2
810.0	1484.2
830.0	1484.4
870.0	1484.1
900.0	1484.4
980.0	1485.2
1000.0	1485.1
1050.0	1485.5
1100.0	1486.1
1200.0	1486.8
1300.0	1488.0
1400.0	1489.2
1500.0	1490.5
1600.0	1492.3
1800.0	1495.1
2000.0	1498.0
2200.0	1501.3
2500.0	1505.4
3000.0	1512.1
3500.0	1519.2
4000.0	1527.1
4500.0	1535.9
4752.0	1540.4

RANGE 52.7 NM

DEPTH	SOUND SPEED
0.0	1530.4
15.0	1530.5
35.0	1529.8
60.0	1530.2
75.0	1527.4
85.0	1530.0
100.0	1528.6
110.0	1522.8
120.0	1527.7
150.0	1510.1
160.0	1511.6
175.0	1510.0
200.0	1508.6
250.0	1504.3
300.0	1500.8
350.0	1497.7
400.0	1494.3
420.0	1494.3
450.0	1492.3
510.0	1489.0
530.0	1488.9
550.0	1488.1
600.0	1485.9
650.0	1485.2
700.0	1484.5
720.0	1484.4
750.0	1484.7
810.0	1484.5
850.0	1484.8
900.0	1485.2
1000.0	1485.4
1060.0	1486.1
1090.0	1485.7
1150.0	1486.8
1200.0	1487.7
1300.0	1488.5
1400.0	1489.7
1500.0	1491.3
1600.0	1492.4
1800.0	1495.1
2000.0	1498.0
2200.0	1501.3
2500.0	1505.4
3000.0	1512.1
3500.0	1519.2
4000.0	1527.1
4500.0	1535.9
4750.0	1540.4

RANGE 55.1 NM

DEPTH	SOUND SPEED
0.0	1529.1
20.0	1529.2
40.0	1528.3
55.0	1528.6
75.0	1522.5
85.0	1520.9
95.0	1521.5
130.0	1515.0
140.0	1516.9
150.0	1513.4
155.0	1513.8
175.0	1509.7
200.0	1505.8
250.0	1502.6
300.0	1498.9
350.0	1496.2
400.0	1493.6
450.0	1491.5
500.0	1488.9
550.0	1486.7
600.0	1485.3
650.0	1484.4
690.0	1483.9
710.0	1484.0
750.0	1483.7
780.0	1483.6
800.0	1483.8
860.0	1483.8
900.0	1484.0
950.0	1484.4
990.0	1484.8
1000.0	1485.4
1100.0	1485.8
1200.0	1487.7
1300.0	1488.5
1400.0	1489.7
1500.0	1491.3
1600.0	1492.4
1800.0	1495.6
2000.0	1498.3
2200.0	1501.3
2500.0	1505.4
3000.0	1512.1
3500.0	1519.2
4000.0	1527.1
4500.0	1535.9
4750.0	1540.4

RANGE 58.6 NM

DEPTH	SOUND SPEED
0.0	1525.5
20.0	1525.8
40.0	1524.8
65.0	1520.7
70.0	1521.0
75.0	1520.9
90.0	1524.4
100.0	1521.3
125.0	1517.4
150.0	1513.0
175.0	1510.2
200.0	1505.7
250.0	1501.5
260.0	1501.2
300.0	1497.4
350.0	1493.9
360.0	1493.7
400.0	1490.8
420.0	1489.7
440.0	1489.5
490.0	1486.1
500.0	1486.0
550.0	1484.7
600.0	1483.3
660.0	1482.6
690.0	1482.7
710.0	1482.4
750.0	1482.8
780.0	1482.3
820.0	1482.9
870.0	1483.3
950.0	1484.7
1000.0	1485.2
1100.0	1486.3
1200.0	1487.1
1300.0	1488.2
1400.0	1489.7
1500.0	1491.2
1600.0	1492.6
1800.0	1495.2
2000.0	1498.0
2200.0	1500.4
2500.0	1504.6
3000.0	1511.3
3500.0	1519.0
4000.0	1526.9
4500.0	1535.9
4744.0	1540.3

RANGE 61.1 NM

DEPTH	SOUND SPEED
0.0	1526.8
20.0	1527.1
45.0	1526.5
60.0	1525.7
65.0	1525.8
75.0	1521.8
80.0	1521.8
100.0	1518.4
105.0	1519.5
125.0	1511.4
145.0	1508.0
150.0	1508.1
185.0	1506.3
200.0	1505.1
220.0	1504.3
230.0	1504.3
290.0	1498.4
310.0	1497.3
350.0	1495.6
390.0	1491.8
400.0	1491.4
460.0	1488.3
500.0	1487.1
530.0	1486.1
600.0	1484.5
650.0	1483.2
700.0	1482.4
740.0	1482.0
800.0	1482.7
850.0	1483.0
900.0	1483.8
950.0	1484.8
1000.0	1485.2
1100.0	1486.3
1200.0	1487.1
1300.0	1488.2
1400.0	1489.7
1500.0	1491.2
1600.0	1492.6
1800.0	1495.2
2000.0	1498.0
2200.0	1500.4
2500.0	1504.6
3000.0	1511.3
3500.0	1519.0
4000.0	1526.9
4500.0	1535.9
4729.0	1540.0

RANGE 65.6 NM

DEPTH	SOUND SPEED
0.0	1525.2
27.0	1525.7
61.0	1518.0
69.0	1520.1
75.0	1516.6
82.0	1521.7
101.0	1512.5
132.0	1508.8
169.0	1506.0
184.0	1506.2
205.0	1504.8
219.0	1504.0
249.0	1501.4
302.0	1497.3
338.0	1492.9
394.0	1490.3
448.0	1488.4
501.0	1485.3
548.0	1483.7
598.0	1482.6
618.0	1481.7
633.0	1481.8
671.0	1481.1
685.0	1481.3
713.0	1481.0
750.0	1481.3
799.0	1481.9
855.0	1482.7
900.0	1483.3
1000.0	1484.3
1100.0	1485.4
1200.0	1487.2
1300.0	1488.8
1400.0	1490.2
1500.0	1491.3
1600.0	1492.7
1800.0	1495.6
2000.0	1498.6
2200.0	1501.3
2500.0	1505.4
3000.0	1512.1
3500.0	1519.2
4000.0	1527.1
4500.0	1535.9
4739.0	1540.2

RANGE 68.8 NM

DEPTH	SOUND SPEED
0.0	1523.2
15.0	1523.3
45.0	1520.6
60.0	1520.9
75.0	1519.0
85.0	1521.6
95.0	1516.0
105.0	1512.3
120.0	1515.0
140.0	1513.6
150.0	1513.5
175.0	1511.5
200.0	1509.1
250.0	1502.2
300.0	1498.4
350.0	1493.9
400.0	1491.1
450.0	1488.0
500.0	1485.6
550.0	1484.0
600.0	1482.7
620.0	1482.3
650.0	1482.8
680.0	1482.3
720.0	1482.9
750.0	1482.7
790.0	1482.4
850.0	1482.9
900.0	1483.3
950.0	1483.8
1000.0	1484.3
1100.0	1485.4
1200.0	1487.2
1300.0	1488.8
1400.0	1490.2
1500.0	1491.3
1600.0	1492.7
1800.0	1495.6
1900.0	1497.0
2000.0	1498.0
2200.0	1501.3
2500.0	1505.4
3000.0	1512.1
4000.0	1527.1
4500.0	1535.9
4783.0	1540.8

APPENDIX B

CFIELD SOUND SPEED INTERPOLATION METHOD

Sound speed profile interpolations were constructed using CFIELD; the particular version of CFIELD used for this study was established from Ref. 10, RAYWAVE II. RAYWAVE II is a long-range, low-frequency transmission loss model. Ray theory and wave theory are combined to obtain low-frequency transmission loss estimates. The initial intent of RAYWAVE was to address local environmental conditions, i.e. evaluate in a detailed manner the performance of a single array under very specific environmental conditions. Thus, RAYWAVE was ideal to use for interpolation of SSPs over the restricted environmental area this study was concerned with.

The unique technique used is called the Triangular Sector Method (Ref. 10). It involves constructing triangle cross-sections from adjacent sound speed profile depth values (Figure B1).

Two sound speed profiles, from which the interpolation is to be implemented, are constructed from constant gradient segments. Interface depths are established as points on the gradient segments that are joined and then these depths are positioned on a vertical line at sound speed profile ranges R_A and R_B

(In Figure B1 these line segments join to become the sides of triangles.) These points are connected across each profile to create a series of triangular sectors running from the surface to the sea floor.

The first triangle thus constructed is a right triangle--its vertex is at the profile having the greatest second interface depth, or if the second interface depths coincide, the vertex is placed on the profile with the greatest sound speed gradient.

The other triangles, which generally are not right triangles, are constructed differently. The vertices of the next triangles are placed at depths representing sound speed minima. If neither is a minimum, the triangle sides are selected to subtend the gradient which is closest to the gradient of the preceding triangle. To prevent extreme imbalance in triangle side slope, an additional algorithm is set up such that selected points on a profile may not extend below the next two points on the adjacent profile.

These triangles so generated are the basis for computing the sound speed field used in ray path computations. For determining C(R,Z) for all possible triangular configurations, the following expression is applied (see Figure B2):

$$C(R,Z) = C_V +/- g_r (R-R_V) + g_z (Z_V-Z)$$

where

$g_z = \dfrac{C_2 - C_1}{Z_2 - Z_1}$, is the sound speed gradient in the z-direction

$g_r = \dfrac{C_v - C_x}{R_v - R_s}$, is the sound speed gradient in the R direction

and $C_x = C_1 + g_z\,(Z_v - Z_1)$

Z_v = vertex point depth

C_v = vertex point sound speed

Z_1, C_1 = upper point of open triangle side

Z_2, C_2 = lower point of open triangle side

R_v = range of vertex point

R_s = range of open side of triangle

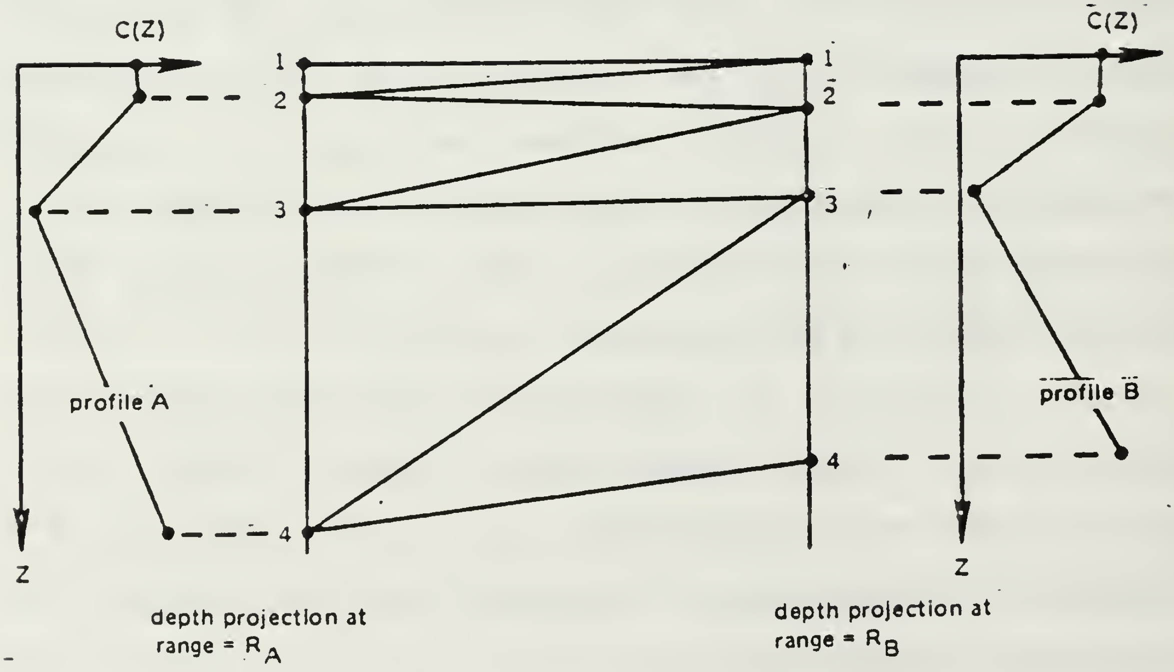


Figure B1. Triangular Sector Description (after Watson, McGirr 1975)

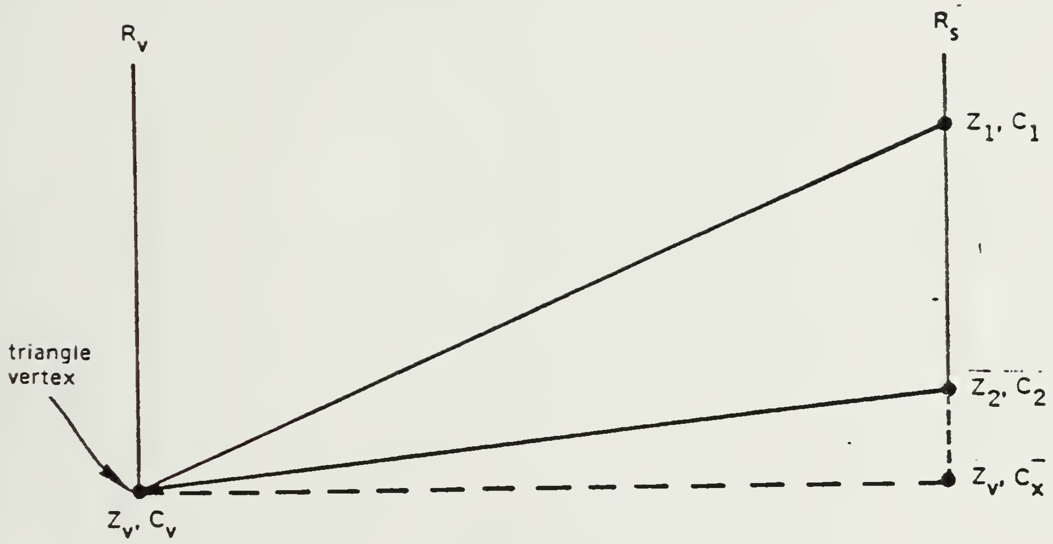
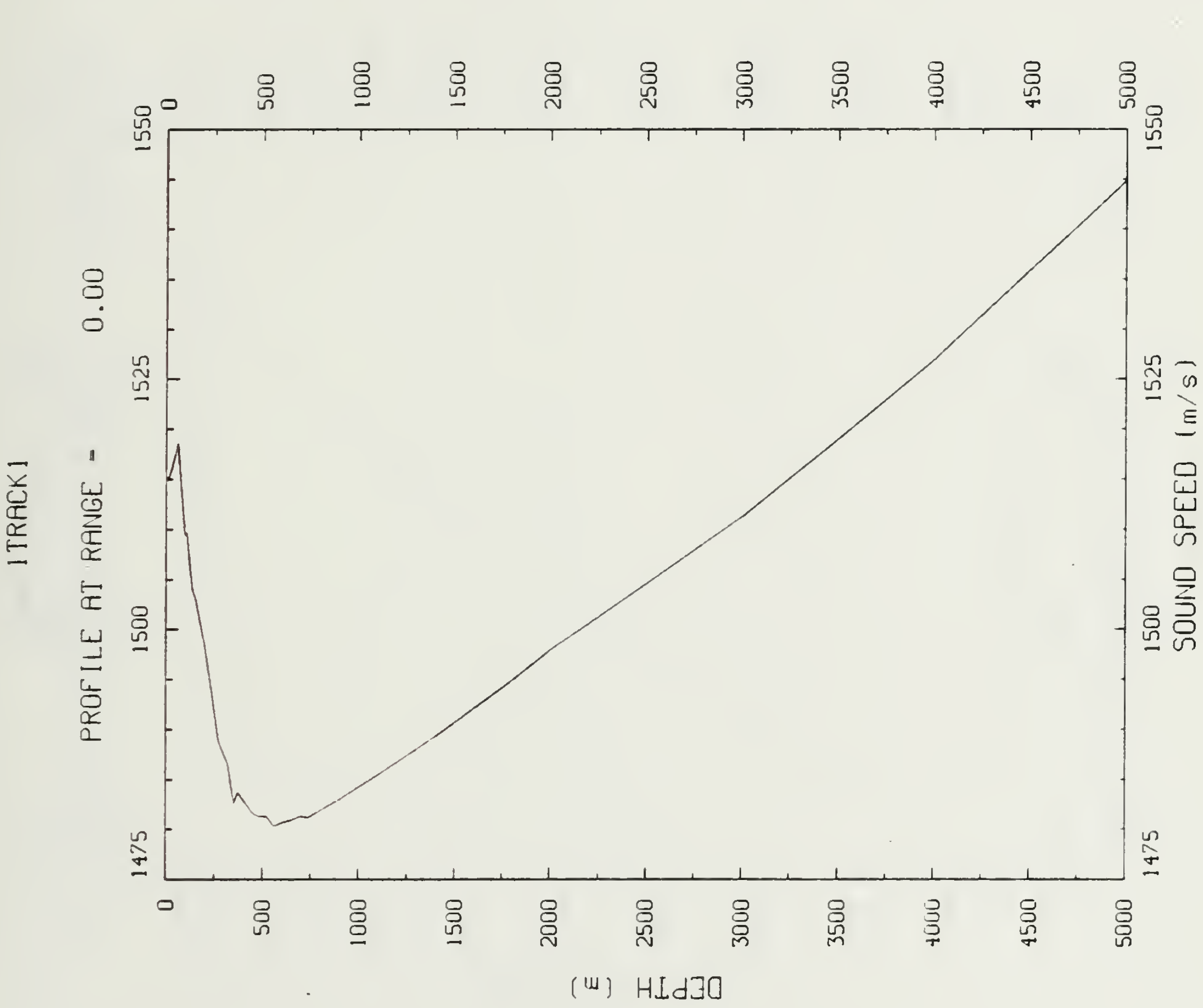


Figure B2. Typical Triangle with Generalized Labels
(after Watson and McGirr, 1975)

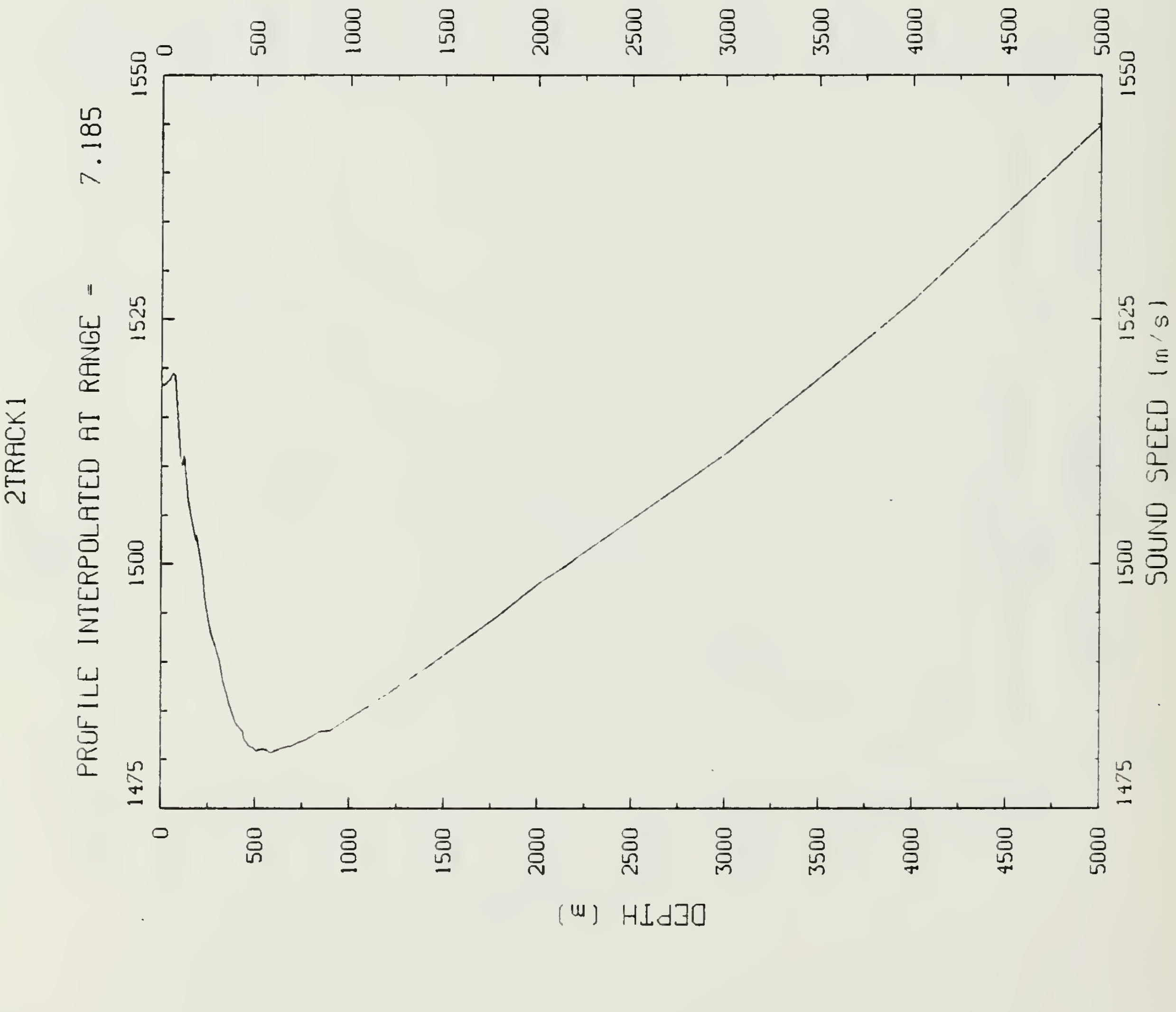
APPENDIX C

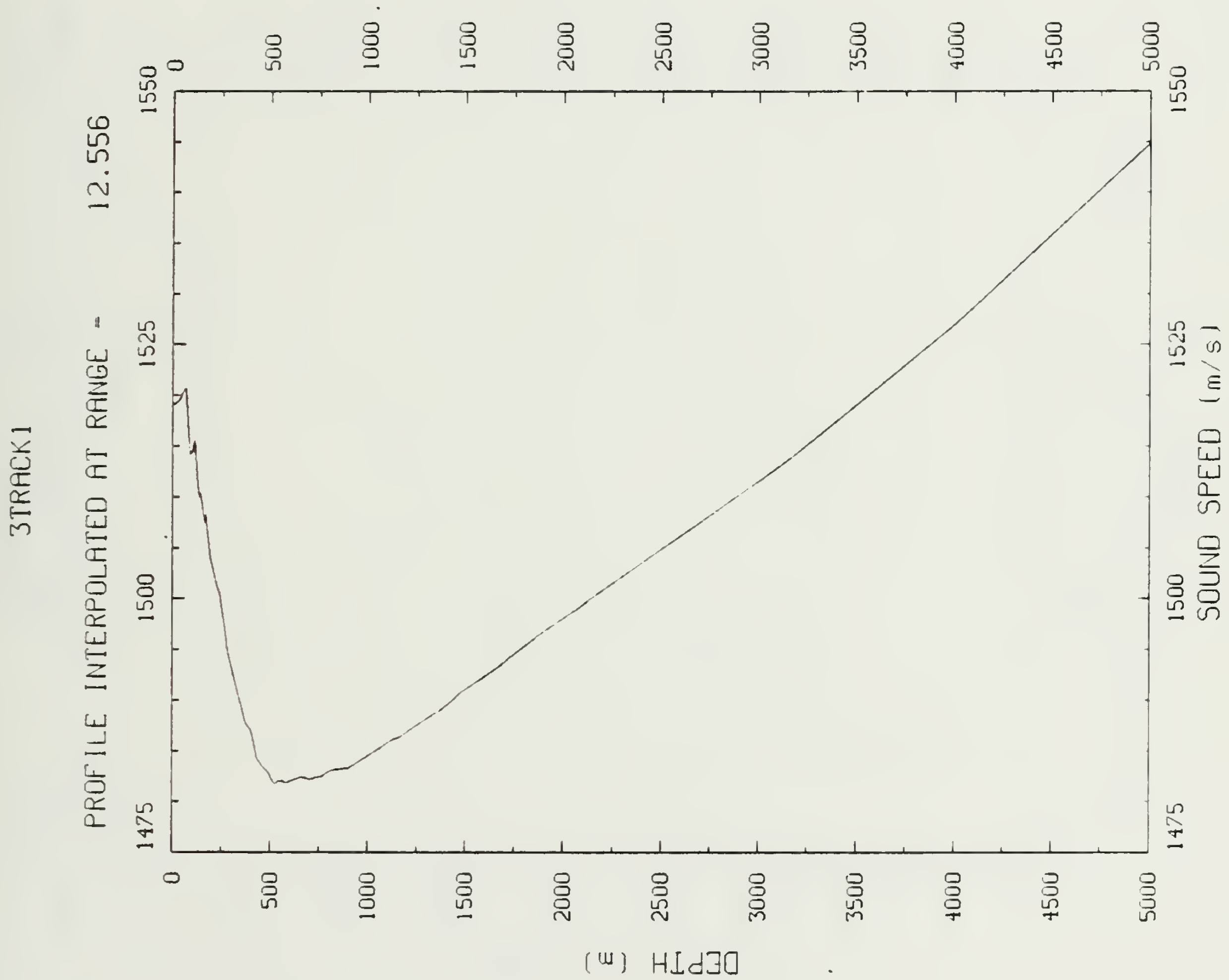
SAMPLE SSP INTERPOLATIONS

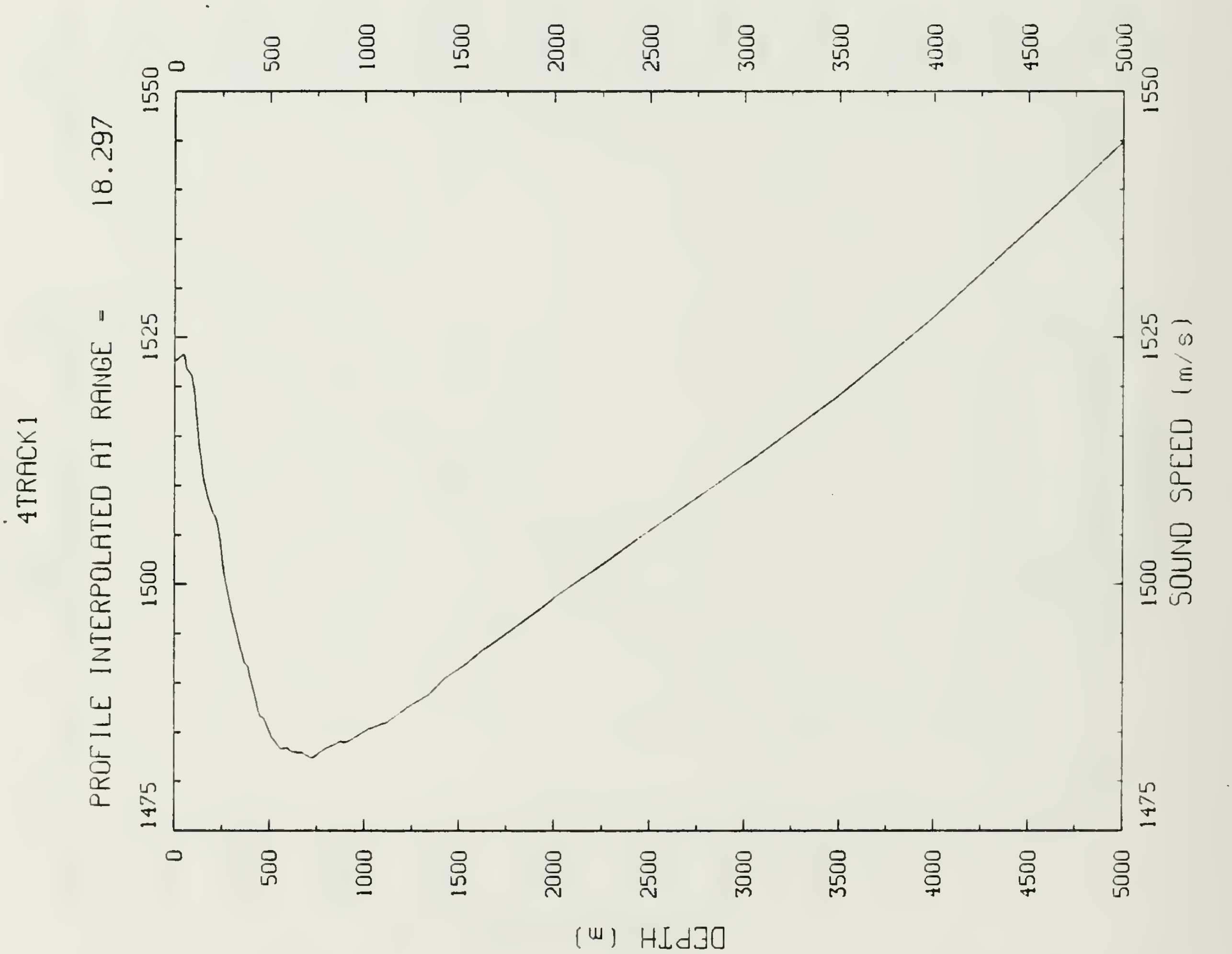
Enclosed are samples of interpolated sound speed profiles generated by CFIELD.

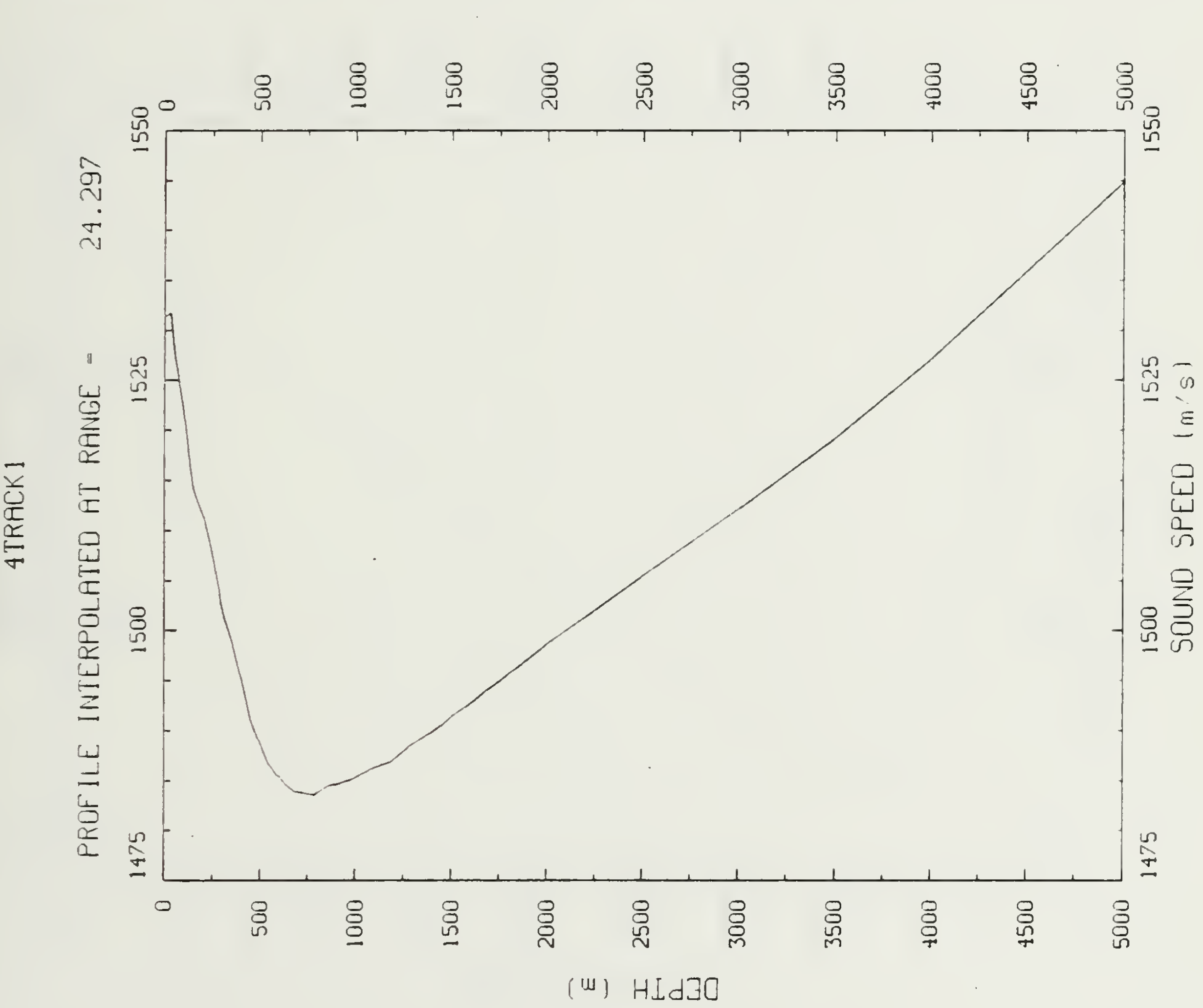


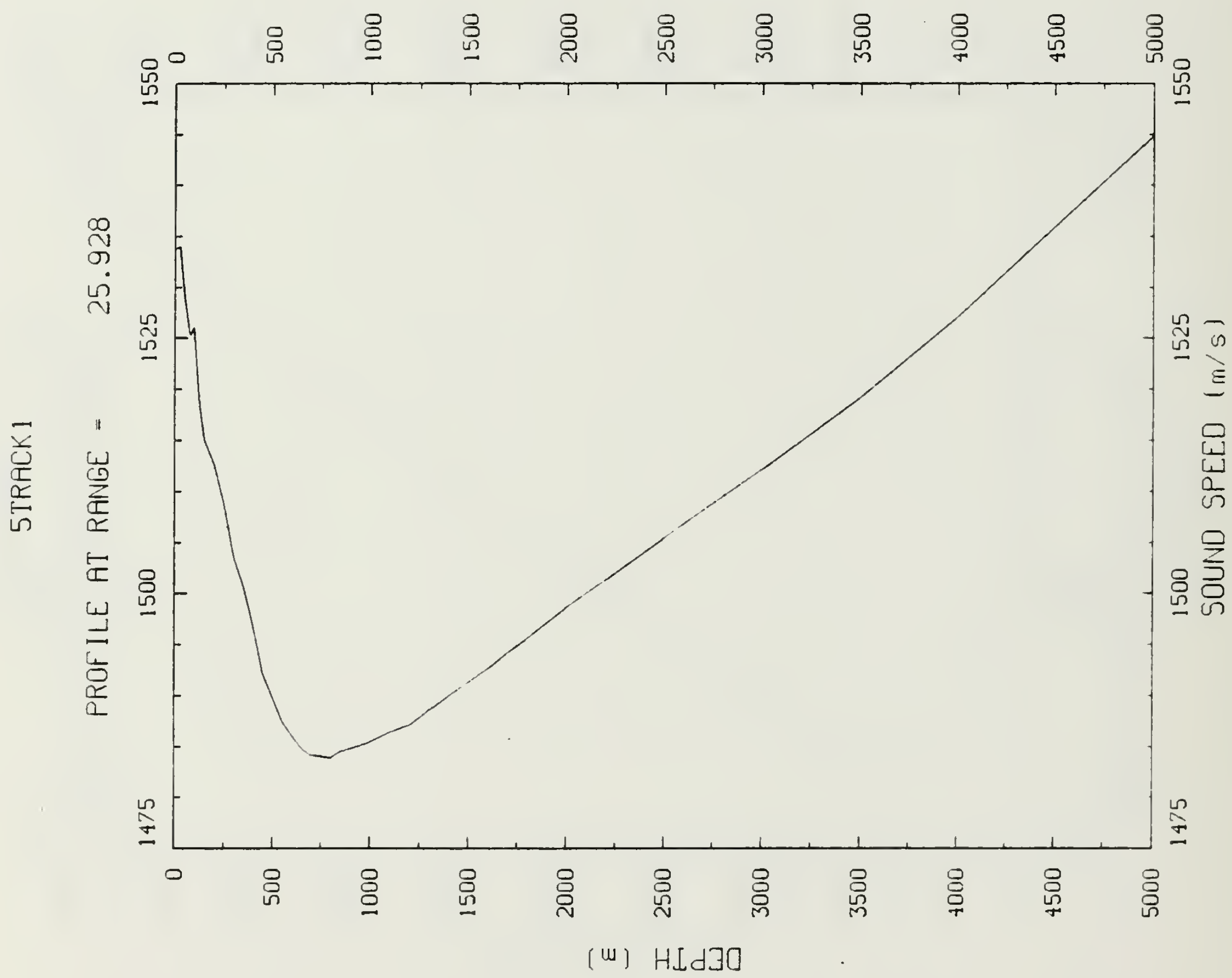
ITRACK1
PROFILE AT RANGE = 0.00
1475
1500
1525
1550
SOUND SPEED (m/s)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
DEPTH (m)

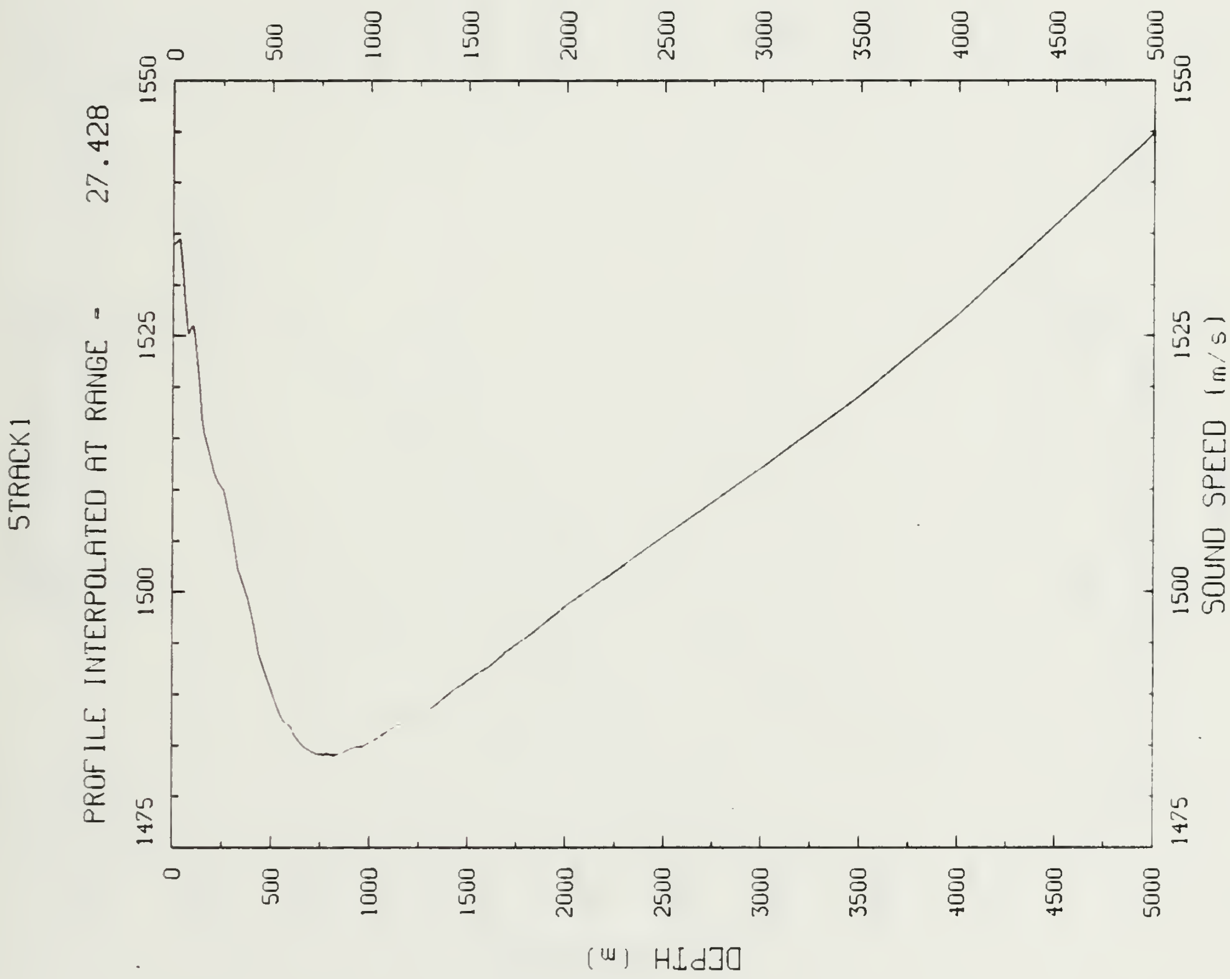

2TRACK1
PROFILE INTERPOLATED AT RANGE = 7.185
DEPTH (m)
SOUND SPEED (m/s)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
1475
1500
1525
1550


3TRACK1
PROFILE INTERPOLATED AT RANGE = 12.556
SOUND SPEED (m/s)
DEPTH (m)
1475
1500
1525
1550
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000

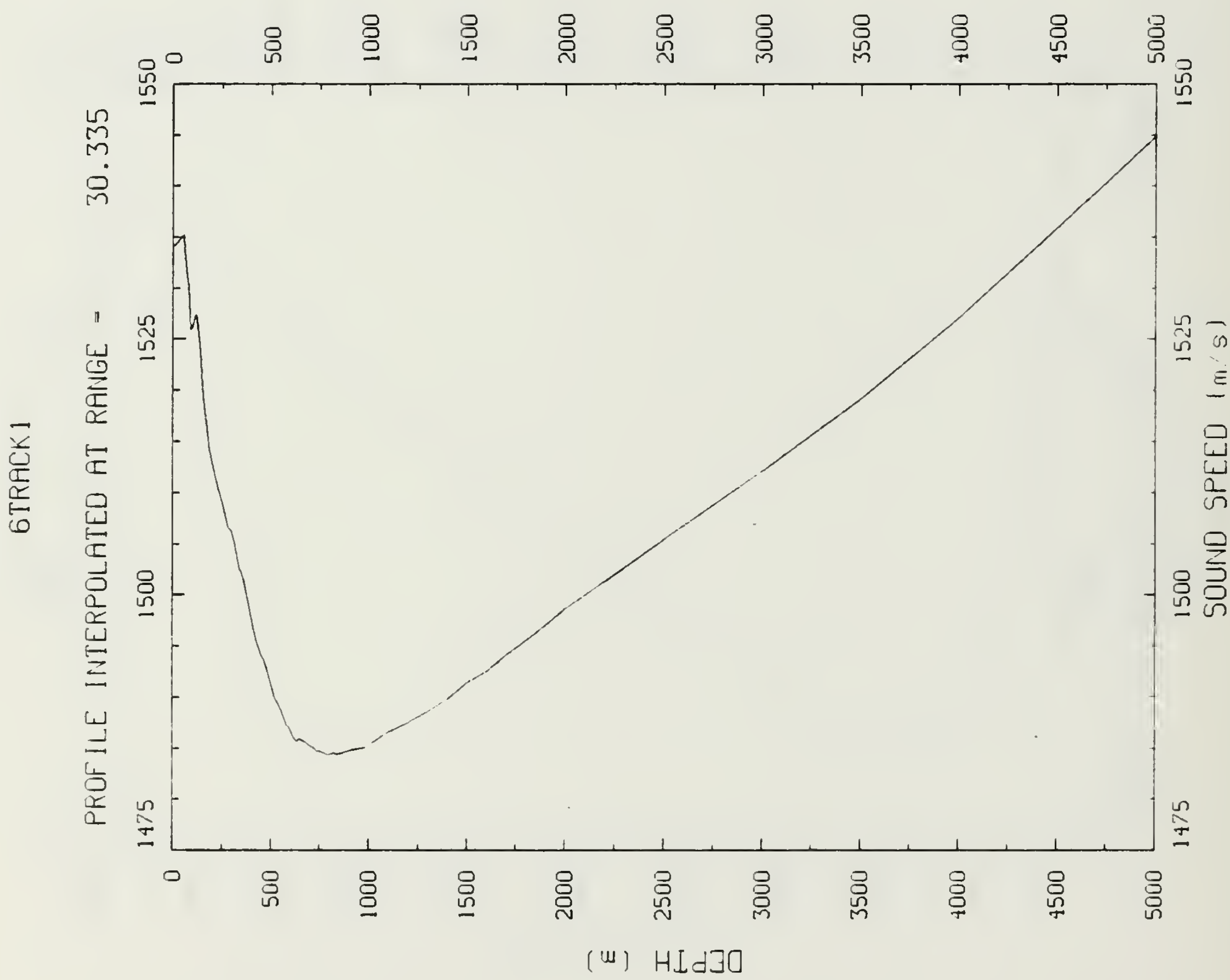

4TRACK1
PROFILE INTERPOLATED AT RANGE = 18.297
1475
1500
1525
1550
SOUND SPEED (m/s)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
DEPTH (m)

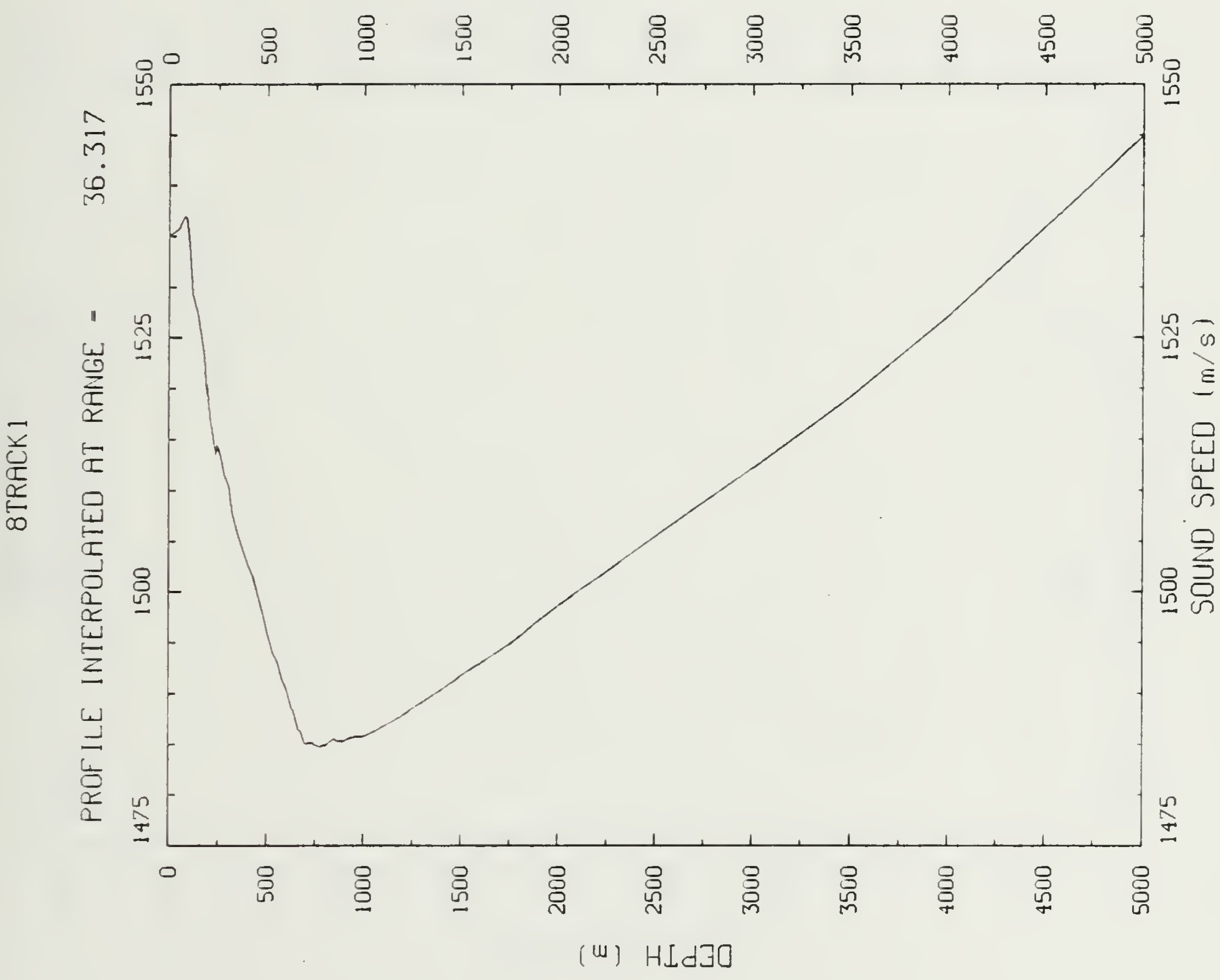

4TRACK1
PROFILE INTERPOLATED AT RANGE = 24.297
1475
1500
1525
1550
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
DEPTH (m)
SOUND SPEED (m/s)


STRACK1
PROFILE AT RANGE = 25.928
SOUND SPEED (m/s)
DEPTH (m)
1475
1500
1525
1550
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000

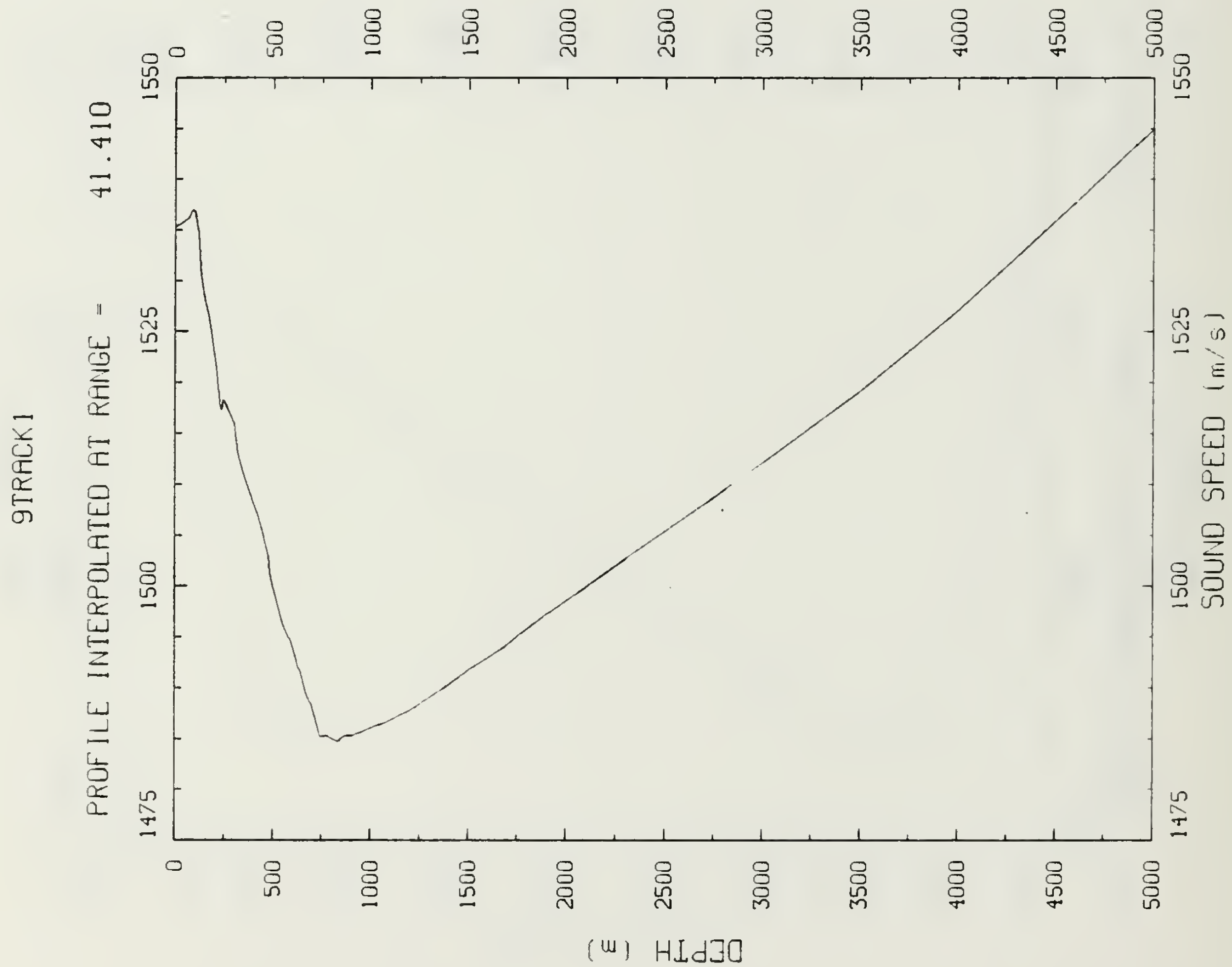


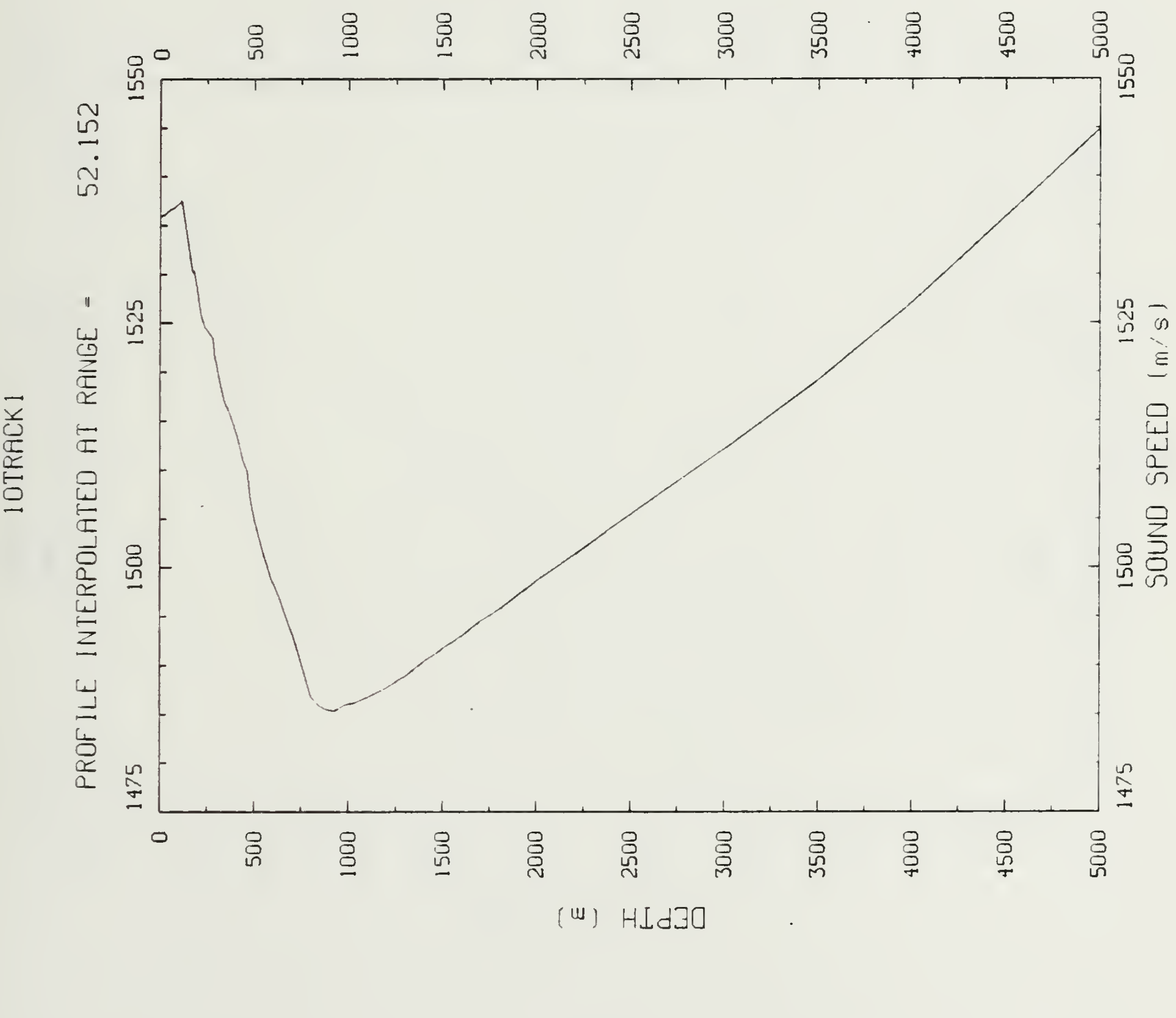
STRACK1
PROFILE INTERPOLATED AT RANGE = 27.428
DEPTH (m)
SOUND SPEED (m/s)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
1475
1500
1525
1550


6TRACK1
PROFILE INTERPOLATED AT RANGE = 30.335
DEPTH (m)
SOUND SPEED (m/s)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
1475
1500
1525
1550

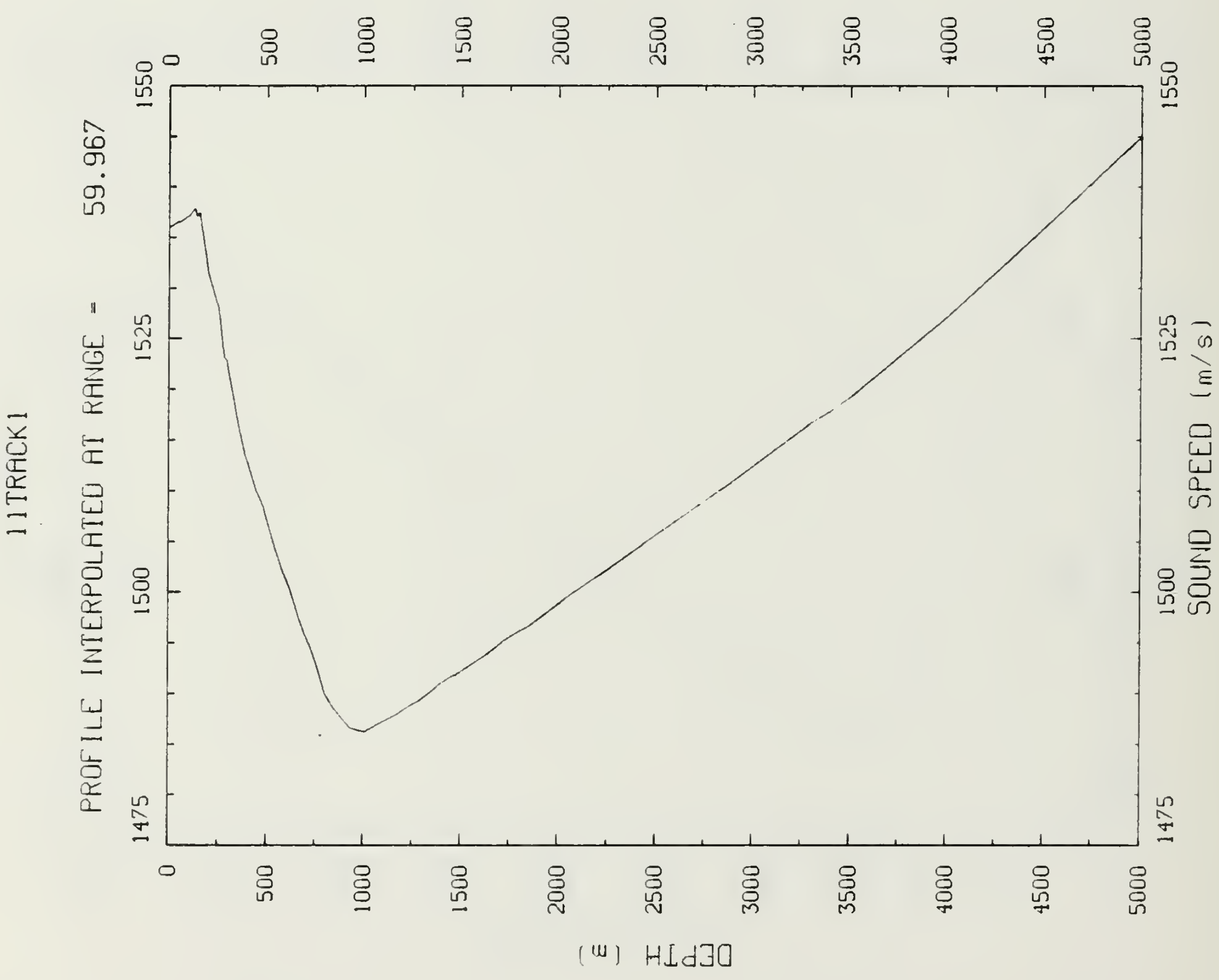


8TRACK1
PROFILE INTERPOLATED AT RANGE - 36.317
DEPTH (m)
SOUND SPEED (m/s)
1475
1500
1525
1550
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000

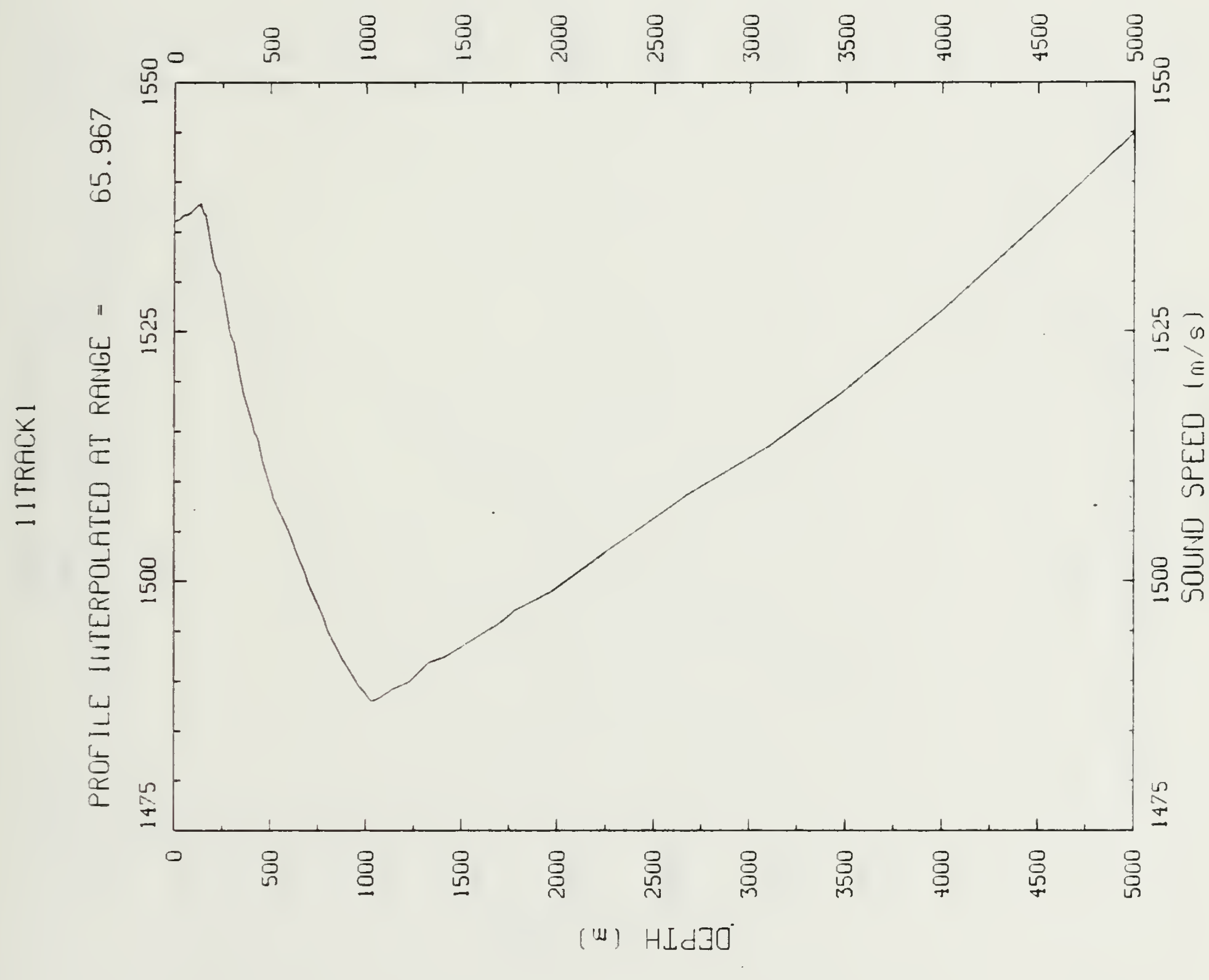

9TRACK1
PROFILE INTERPOLATED AT RANGE = 41.410
1475
1500
1525
1550
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
DEPTH (m)
SOUND SPEED (m/s)



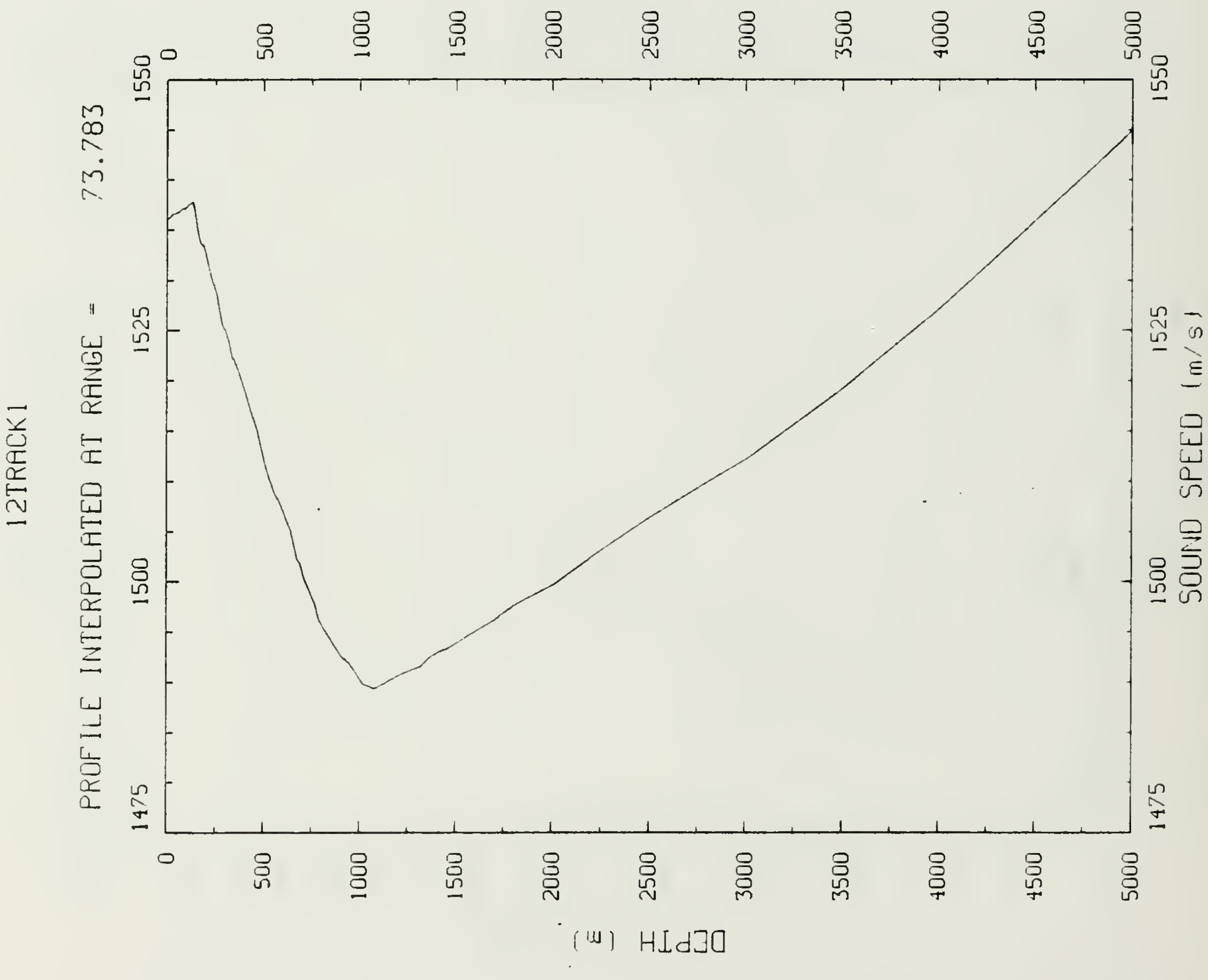
10TRACK1
PROFILE INTERPOLATED AT RANGE = 52.152
DEPTH (m)
SOUND SPEED (m/s)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
1475
1500
1525
1550

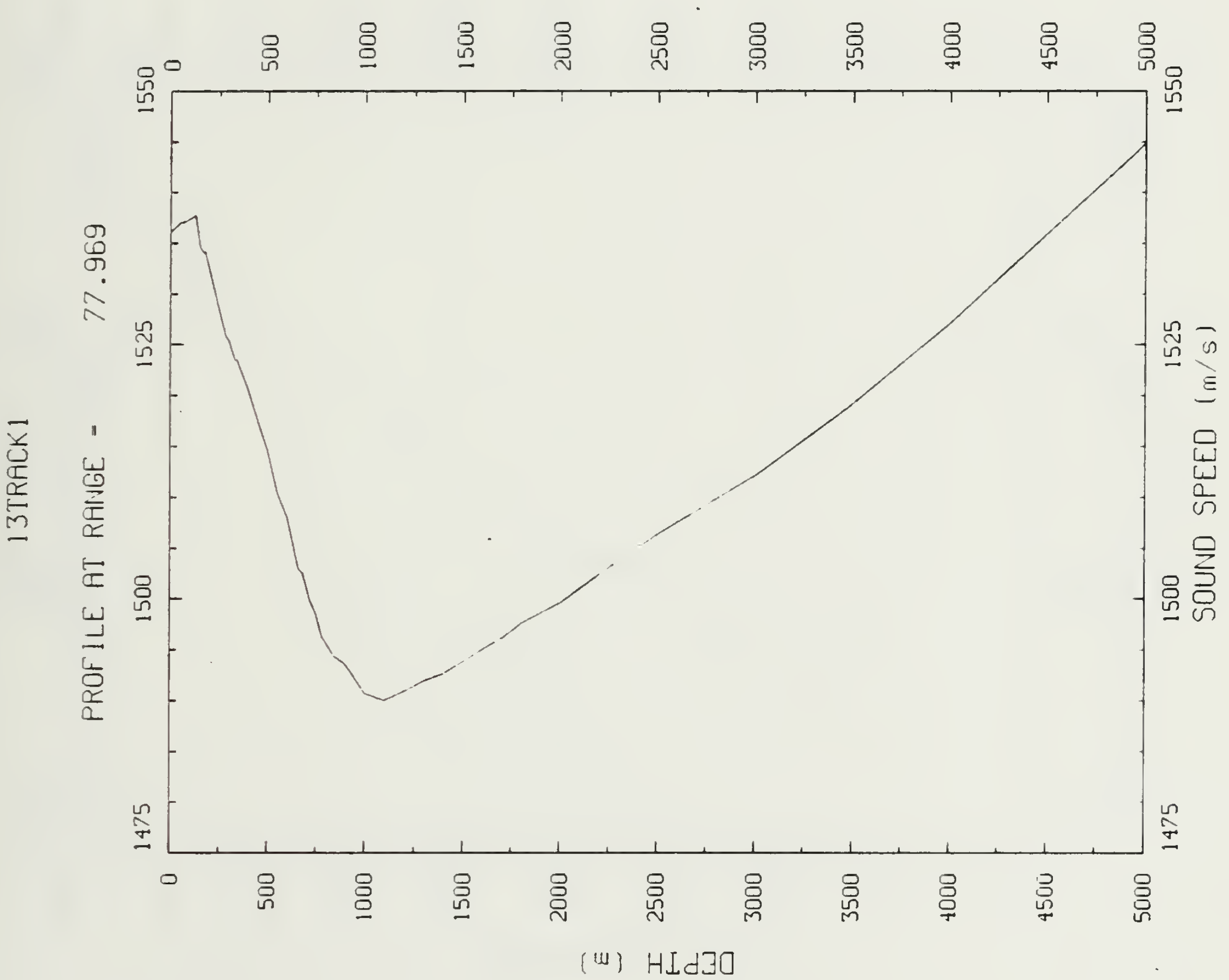


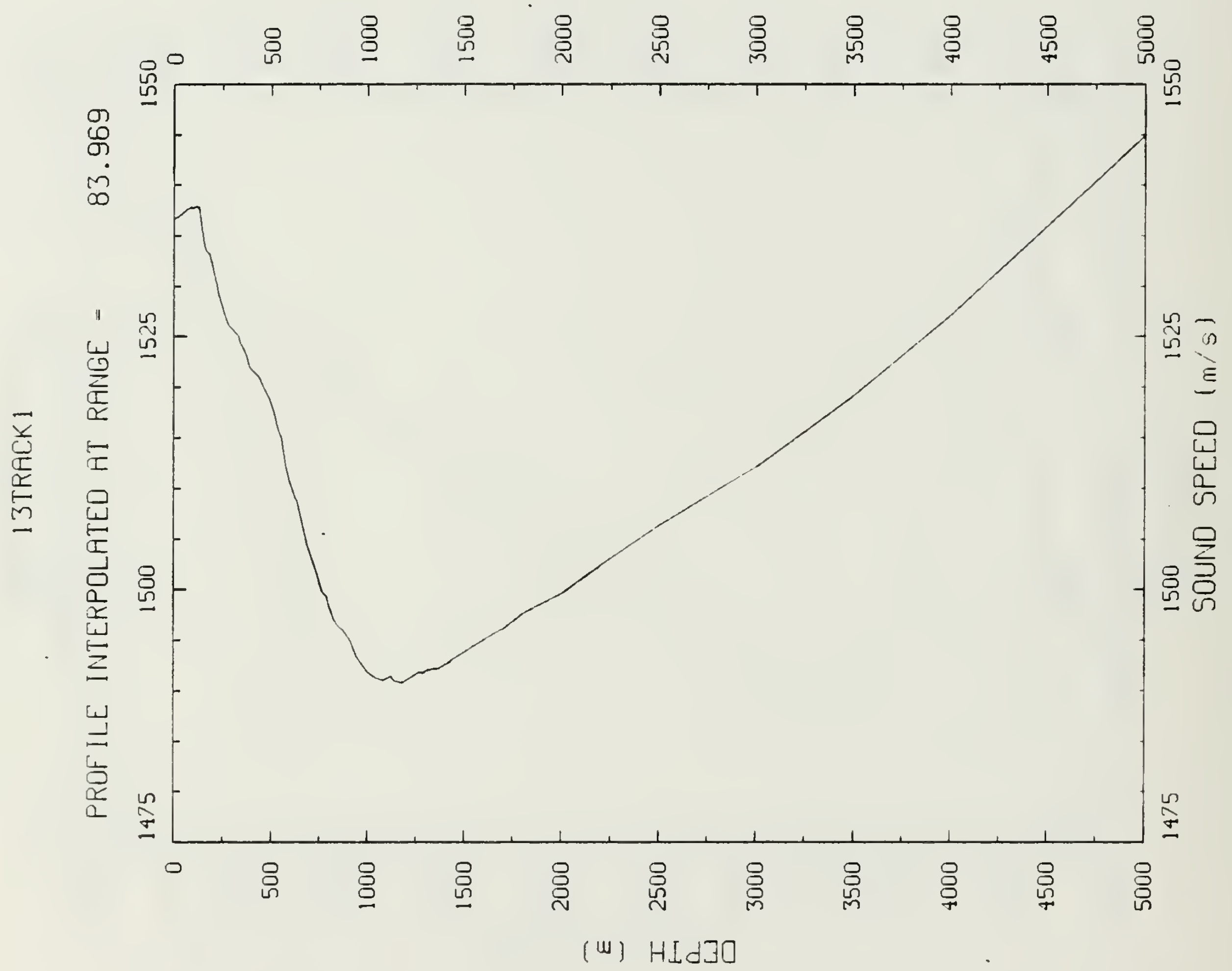
11TRACK1
PROFILE INTERPOLATED AT RANGE = 59.967
DEPTH (m)
SOUND SPEED (m/s)
1475
1500
1525
1550
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000

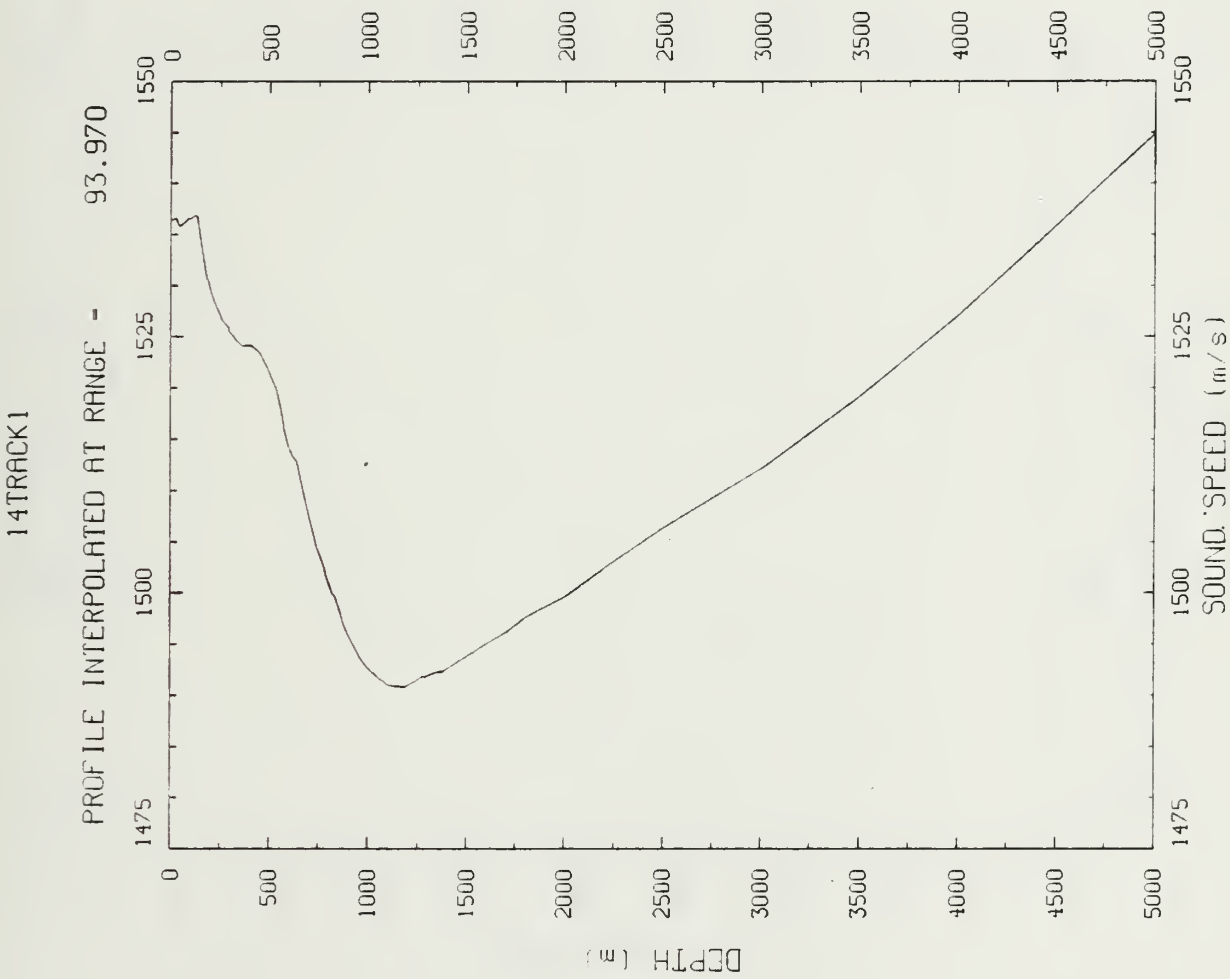


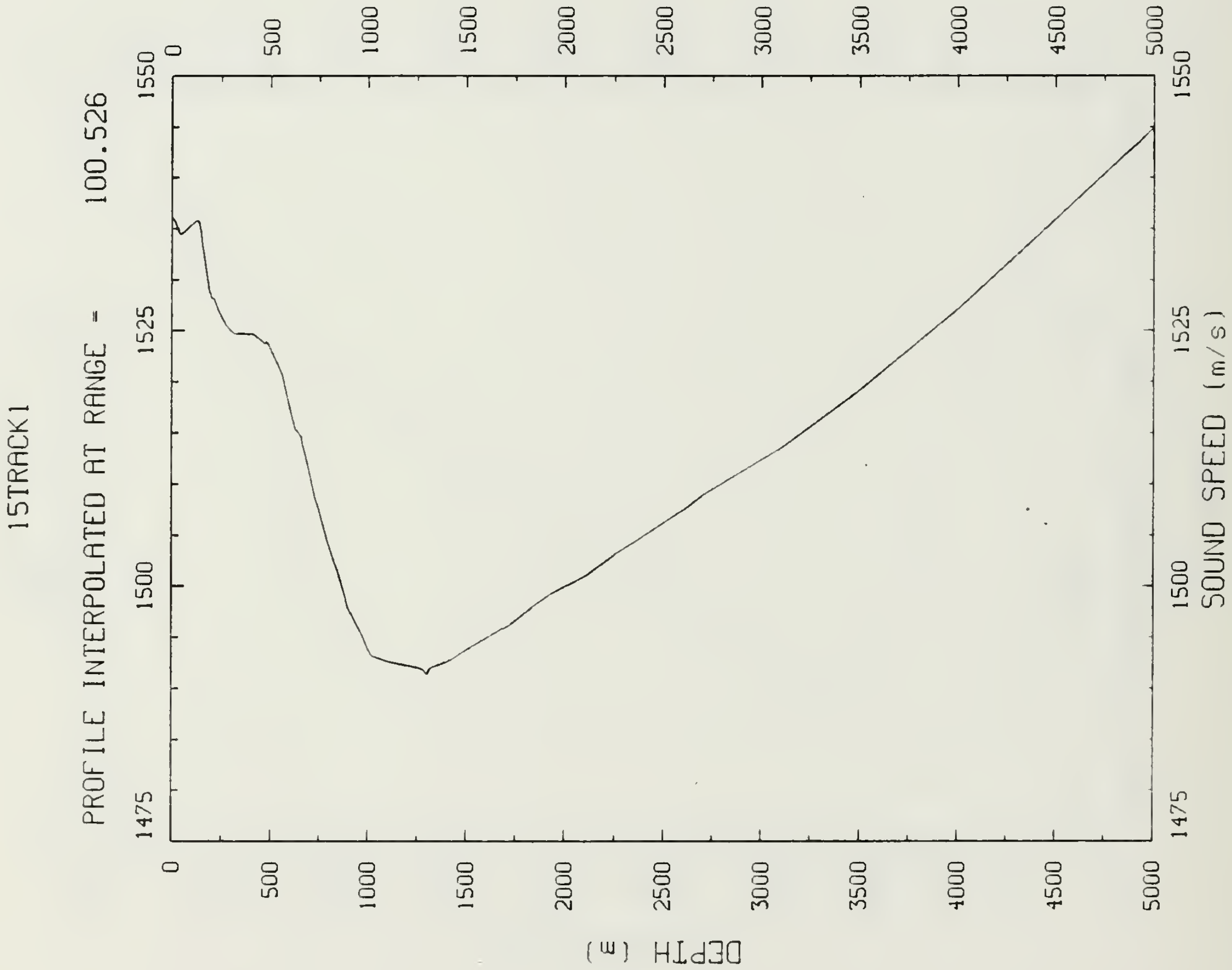
11TRACK1
PROFILE INTERPOLATED AT RANGE = 65.967
1475
1500
1525
1550
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
DEPTH (m)
SOUND SPEED (m/s)

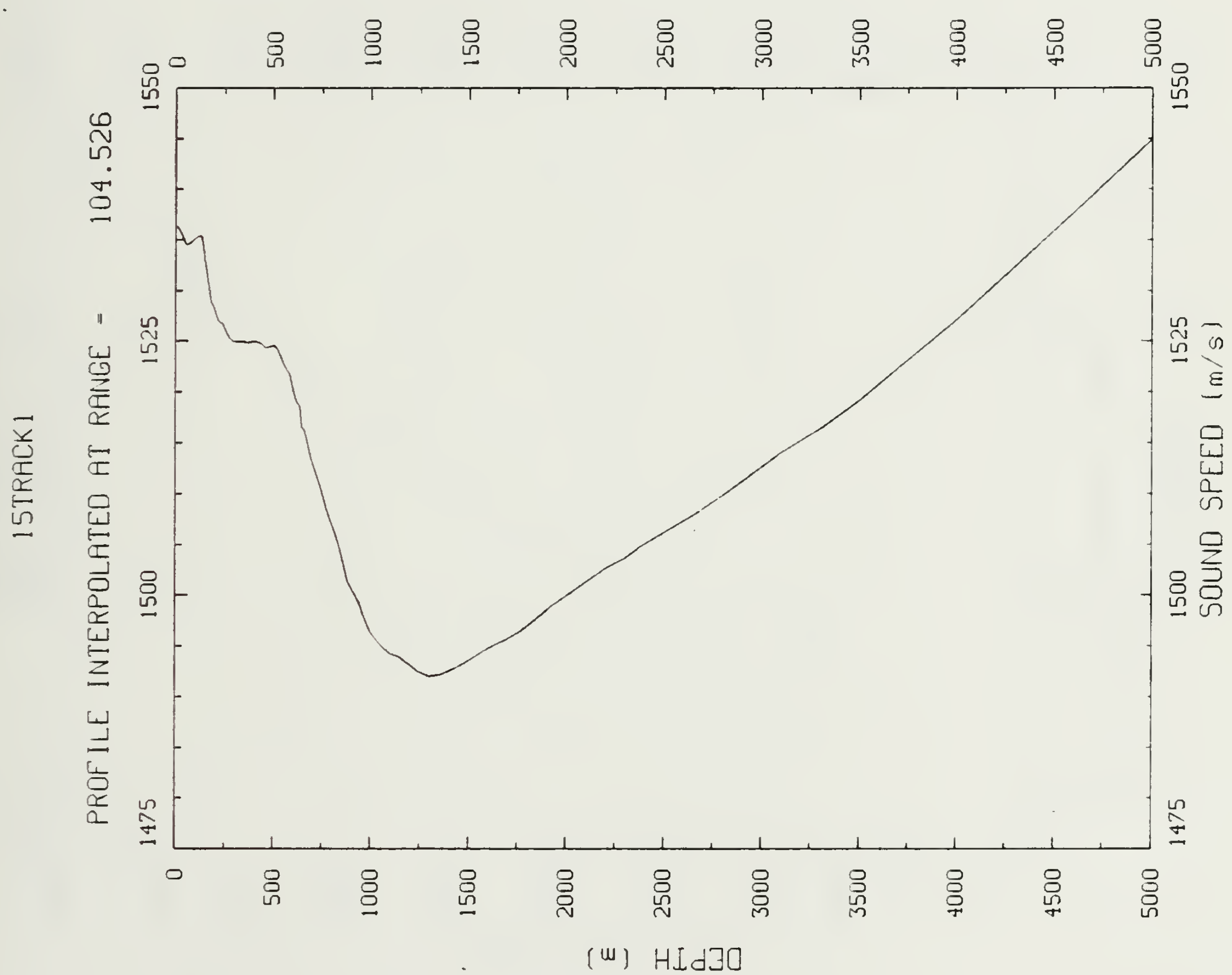

12TRACK1
PROFILE INTERPOLATED AT RANGE = 73.783
1475
1500
1525
1550
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
SOUND SPEED (m/s)
DEPTH (m)

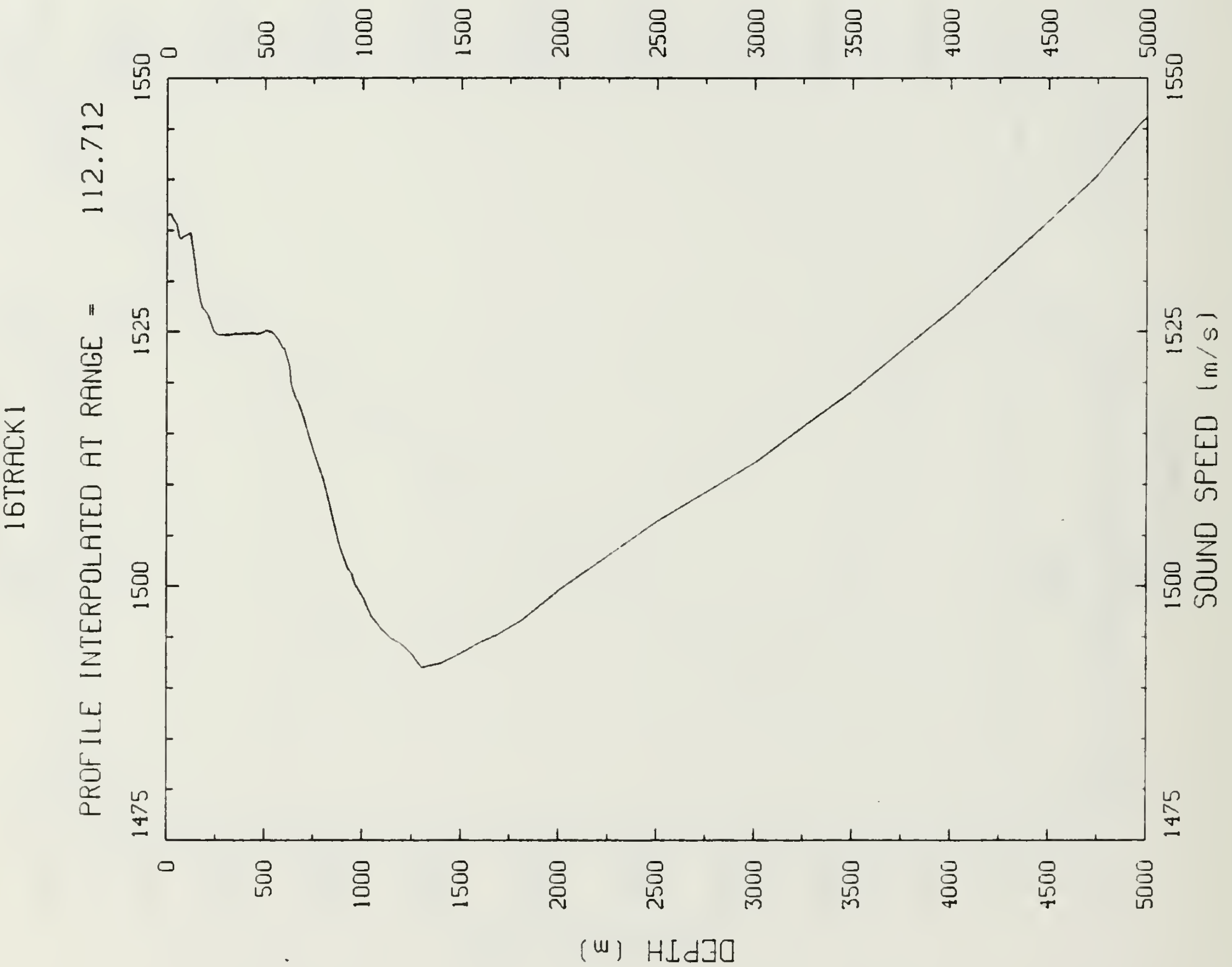

13TRACK1
PROFILE AT RANGE - 77.969
SOUND SPEED (m/s)
DEPTH (m)
1475
1500
1525
1550
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000

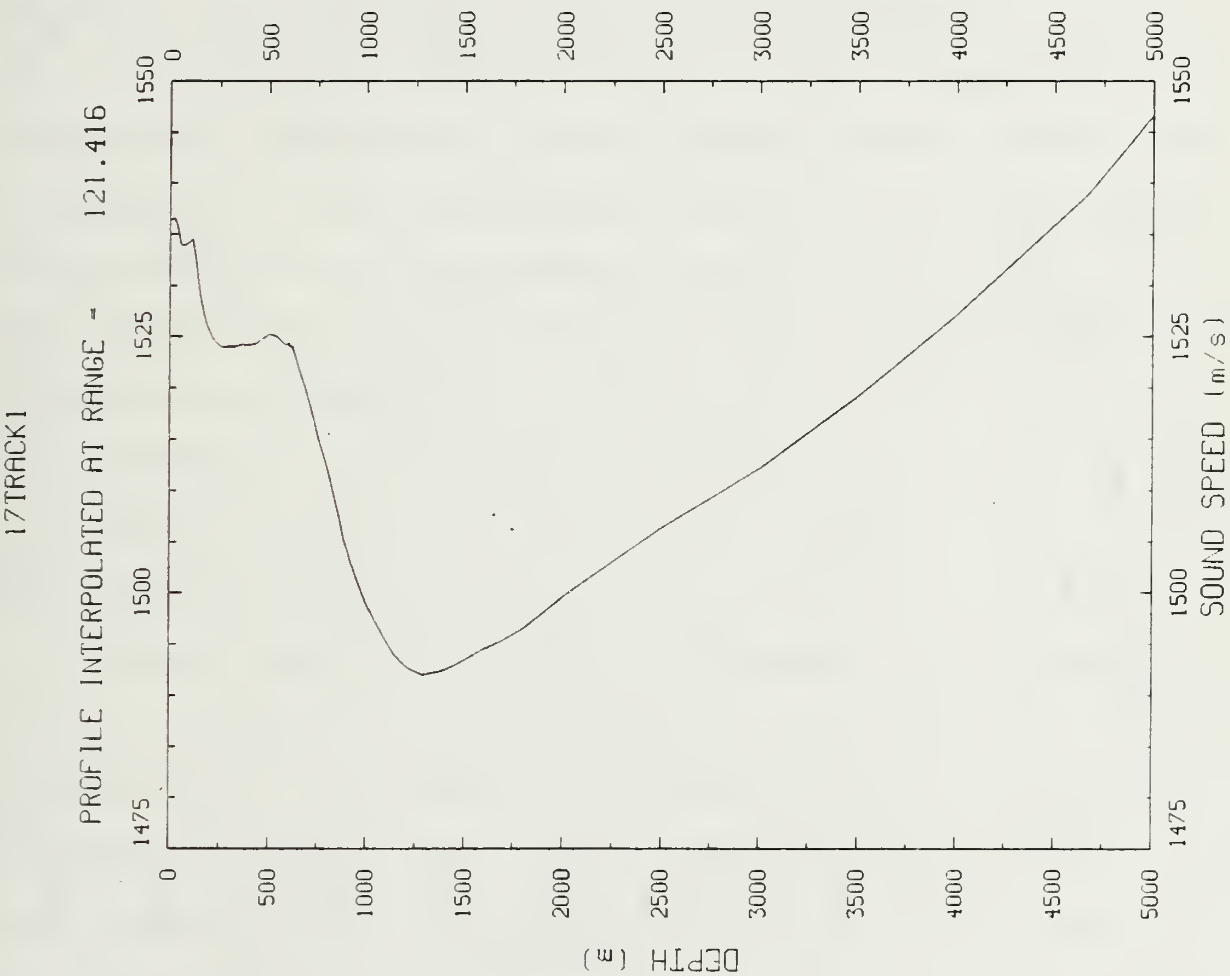

13TRACK1
PROFILE INTERPOLATED AT RANGE - 83.969
DEPTH (m)
SOUND SPEED (m/s)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
1475
1500
1525
1550

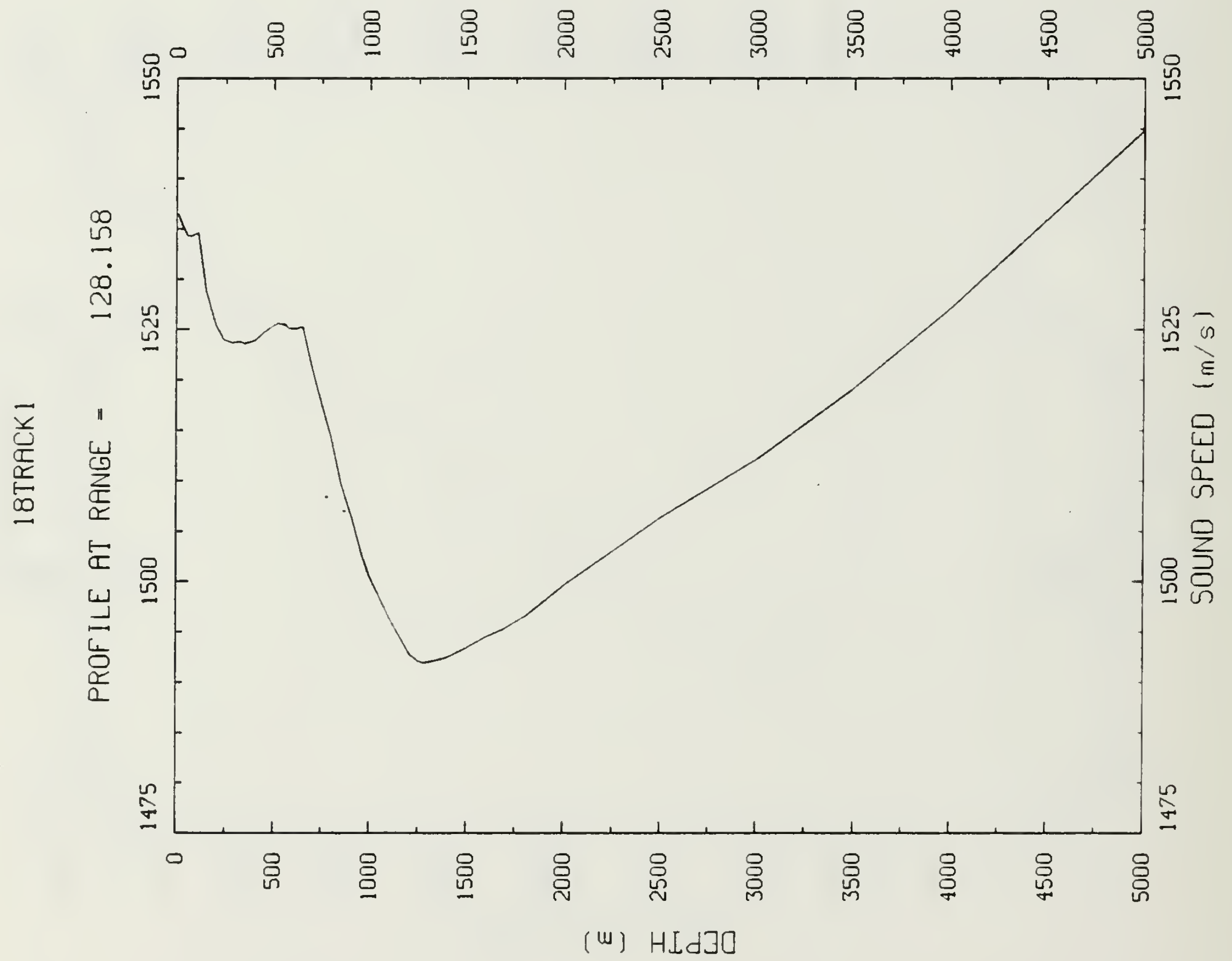

14TRACK1
PROFILE INTERPOLATED AT RANGE - 93.970
SOUND SPEED (m/s)
DEPTH (m)
1475
1500
1525
1550
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000


15TRACK1
PROFILE INTERPOLATED AT RANGE = 100.526
1475
1500
1525
1550
SOUND SPEED (m/s)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
DEPTH (m)


15TRACK1
PROFILE INTERPOLATED AT RANGE = 104.526
DEPTH (m)
SOUND SPEED (m/s)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
1475
1500
1525
1550


16TRACK1
PROFILE INTERPOLATED AT RANGE = 112.712
1475
1500
1525
1550
SOUND SPEED (m/s)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
DEPTH (m)


17TRACK1
PROFILE INTERPOLATED AT RANGE = 121.416
DEPTH (m)
SOUND SPEED (m/s)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
1475
1500
1525
1550



18TRACK1
PROFILE AT RANGE - 128.158
DEPTH (m)
SOUND SPEED (m/s)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
1475
1500
1525
1550

APPENDIX D

TL DIFFERENCE AND GRAYSCALE PLOTTING METHODS

Because an IFDPE output file occupies a tremendous amount of computer storage space, the output file is converted to a binary file. This reduces the space needed in the computer to store the information but it is unreadable in this form as far as the user is concerned. Therefore, the output binary file is processed to create grayscale and TL difference plots which are more readily usable than a binary file.

The programs used to generate grayscale and TL difference plots are:

1) PREGRAY

2) TLDIF

3) GRAYTL

PREGRAY carries out the preprocessing required to create a grayscale/TL difference plot from an IFDPE output file. The complex pressures calculated at user specified ranges and depths are averaged over an incremental range and depth to fit the restrictions of plotting grayscale/TL difference (only a 300 X 400 "matrix" of points is allowed). Those averaged values are then converted to transmisssion loss values and placed in another file to be called up when needed by the next program in creating these graphs.

TLDIF is different from PREGRAY in that it determines the difference in transmission loss values between two different IFDPE output files. If both TL values being differenced are greater than 105 dB, the difference is set to a very small number, since it would not be very significant.

Both PREGRAY and TLDIF supply the necessary axes in range and depth for grayscale/TL difference plotting as well as the bathymetry curves (from the IFDPE input files which includes the bathymetric profile at each SSP along the track) for grayscale/TL difference plotting by using calls to a DISPLA library.

GRAYTL uses the TL values calculated from PREGRAY or TLDIF and calculates a level of gray to represent each of those values. The user inputs a min and max TL value and the grayscale plot graphs only that range of values.

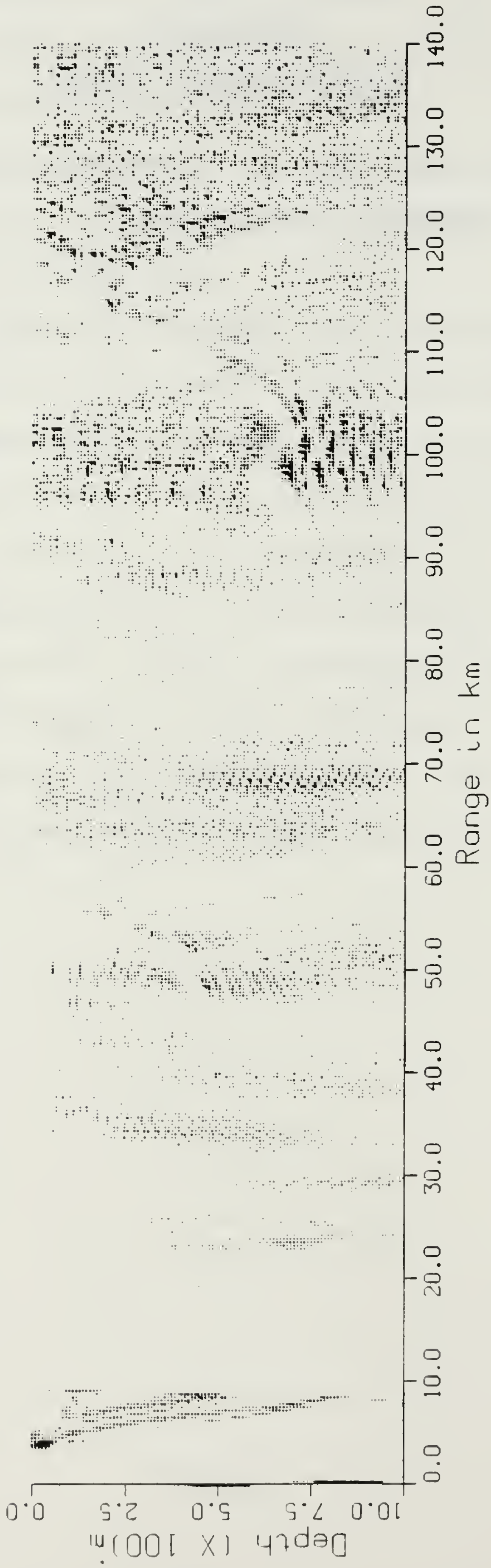
APPENDIX E

TL DIFFERENCE GRAPHS

Enclosed are the TL difference graphs used for qualitative analysis in this report.

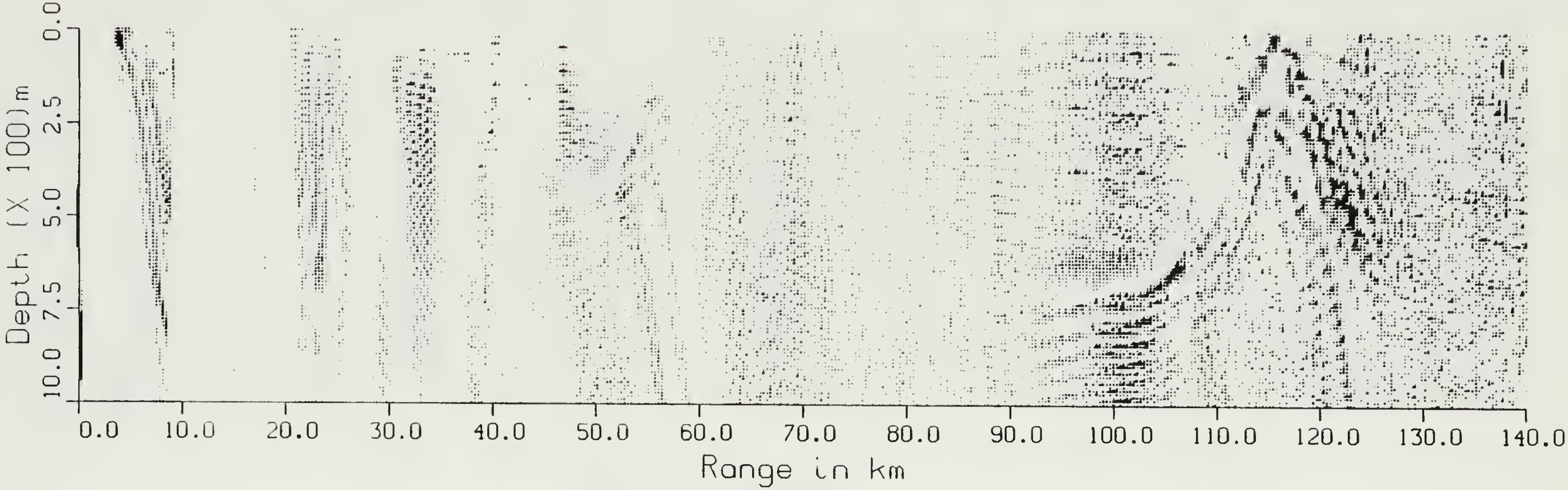
SOURCE DEPTH = 100M

GULF STREAM DIFF RES 2KM AND 6KM



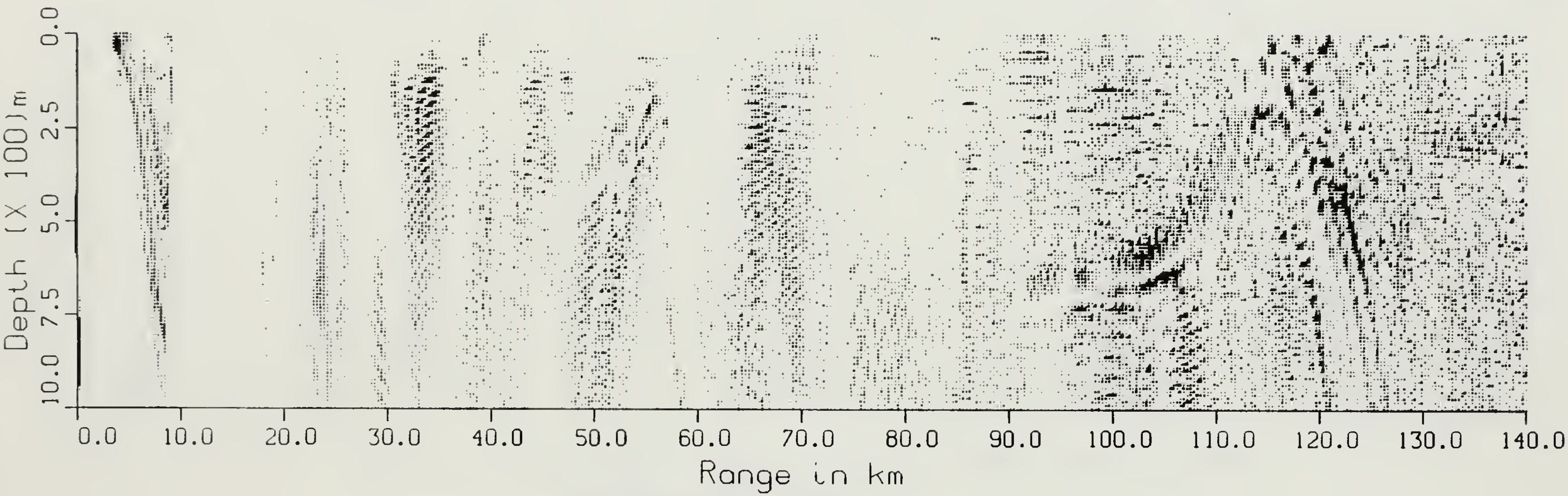
SOURCE DEPTH = 100M

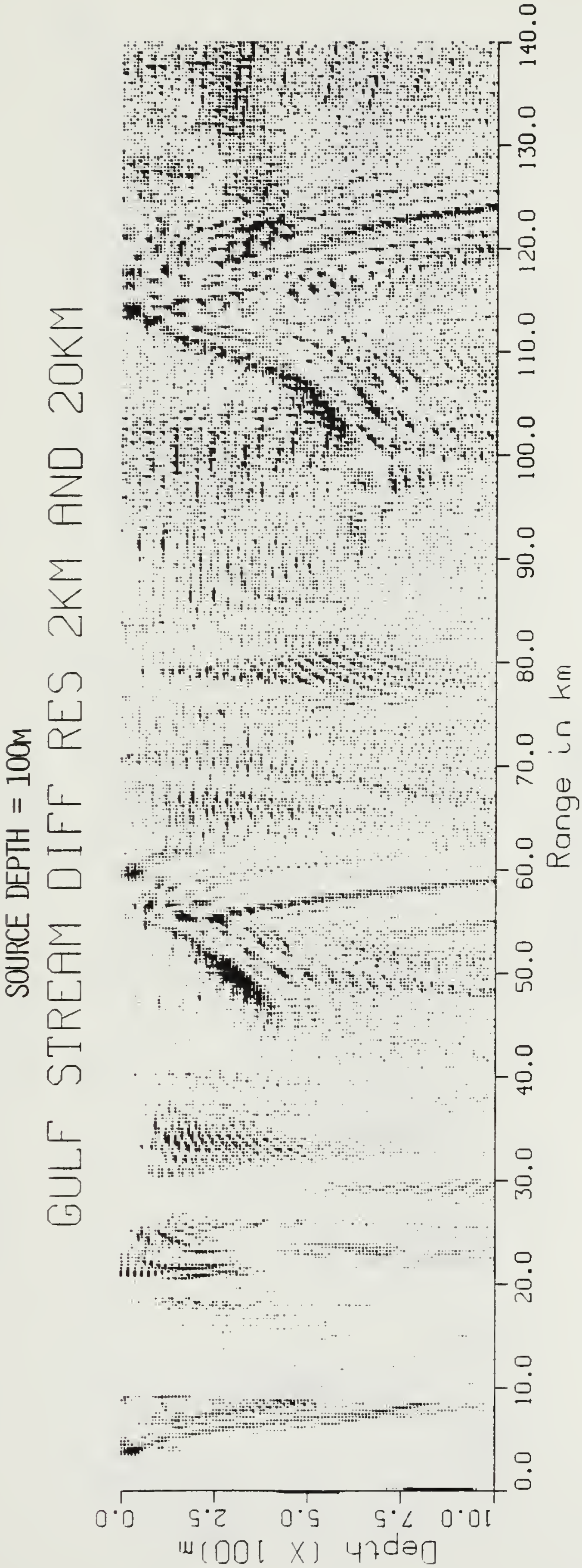
GULF STREAM DIFF RES 2KM AND 8KM



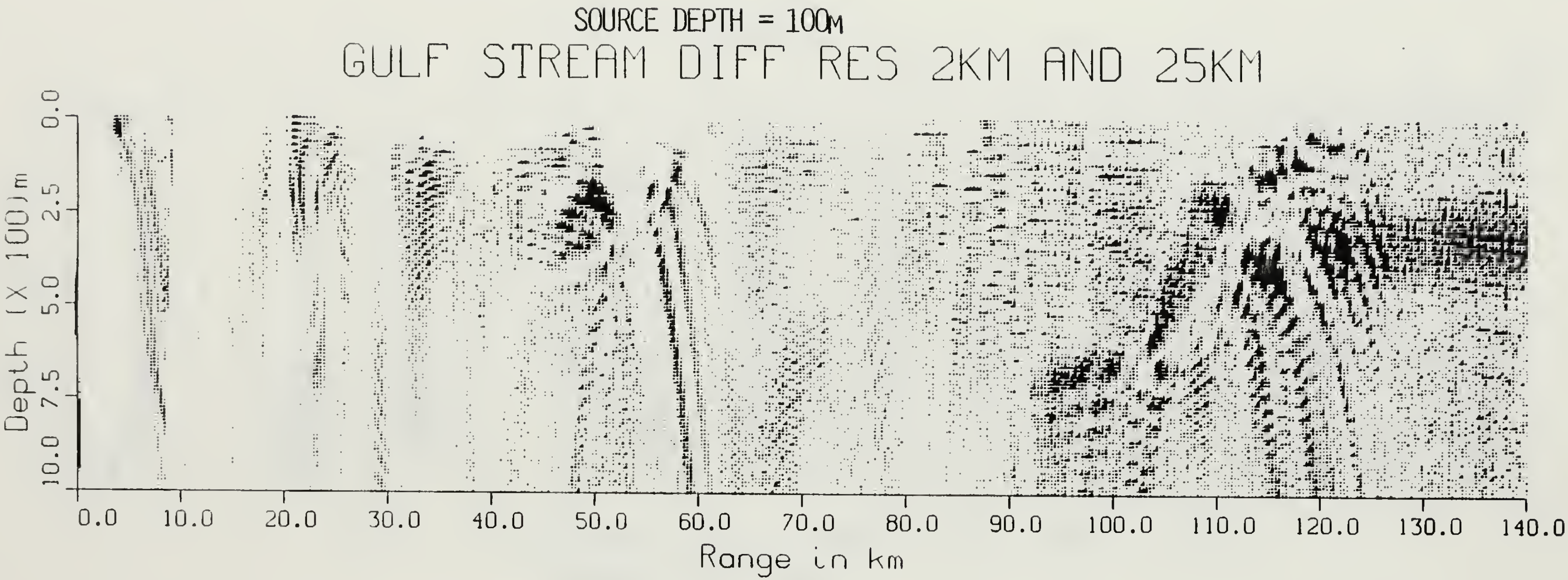
SOURCE DEPTH = 100M

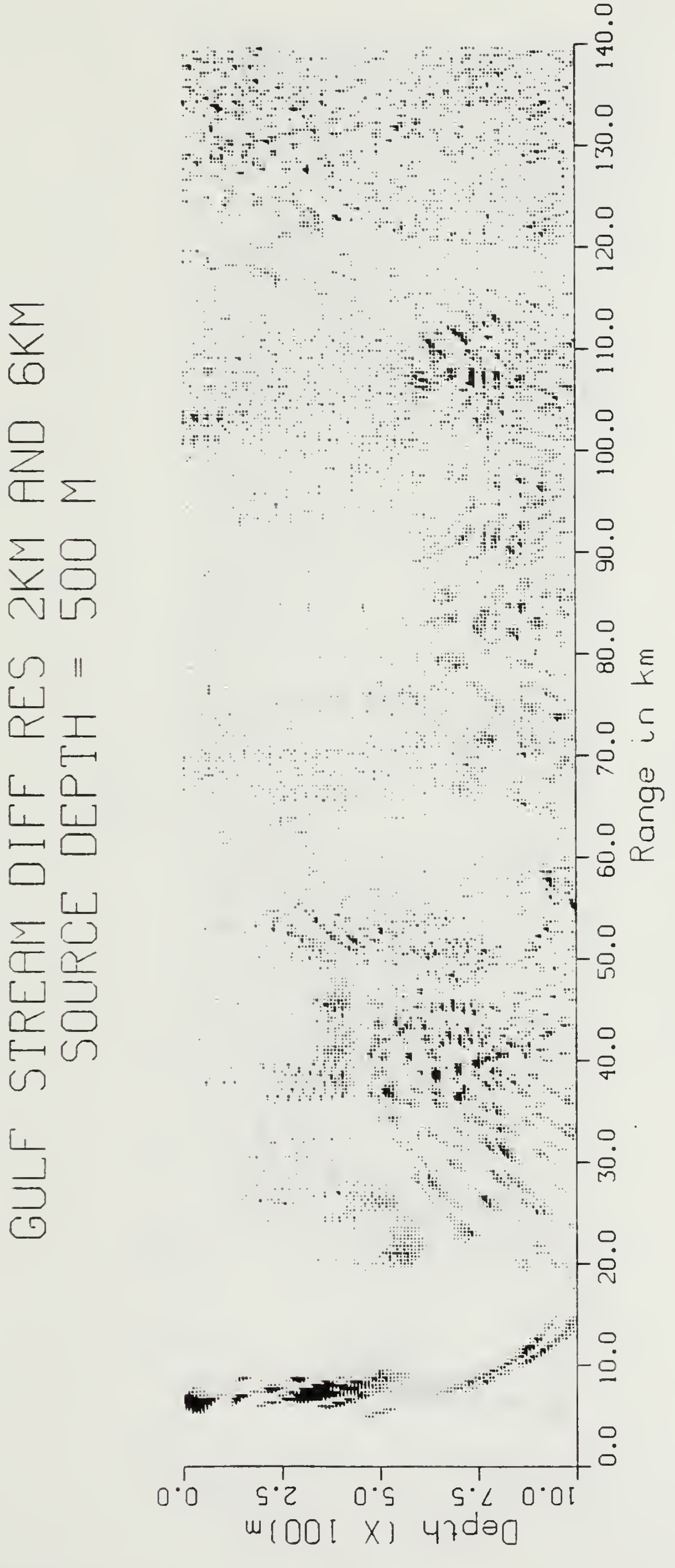
GULF STREAM DIFF RES 2KM AND 10KM



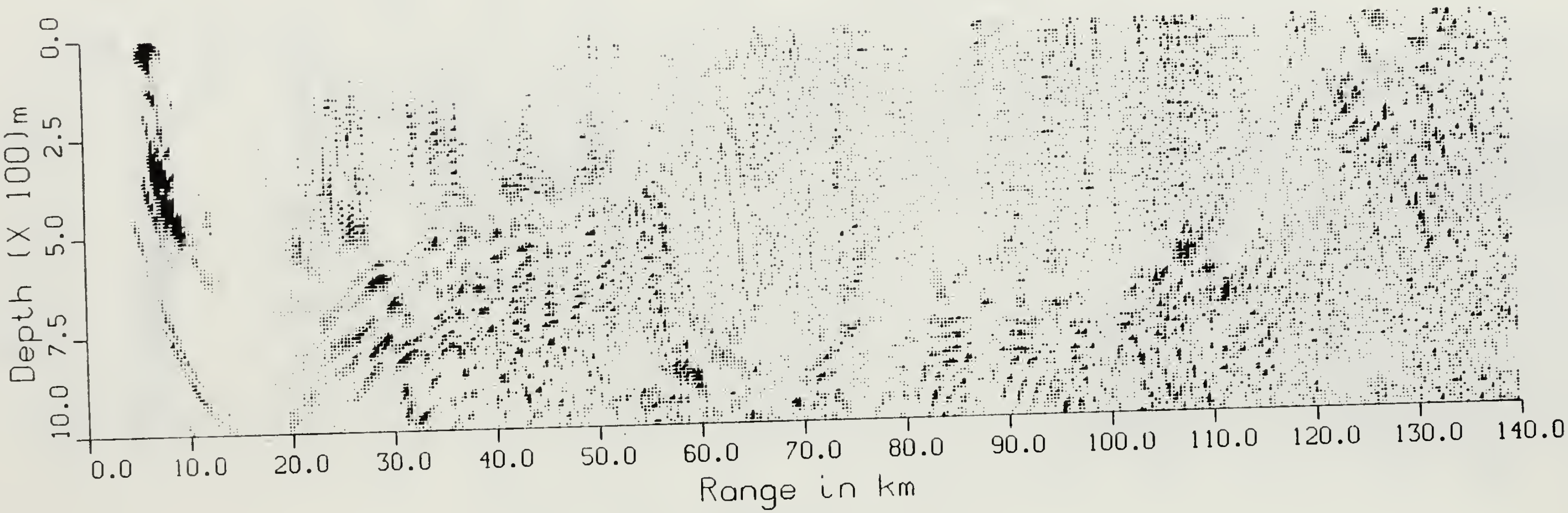


SOURCE DEPTH = 100M
GULF STREAM DIFF RES 2KM AND 20KM
Range in km
Depth (X 100)m
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
120.0
130.0
140.0
0.0
2.5
5.0
7.5
10.0

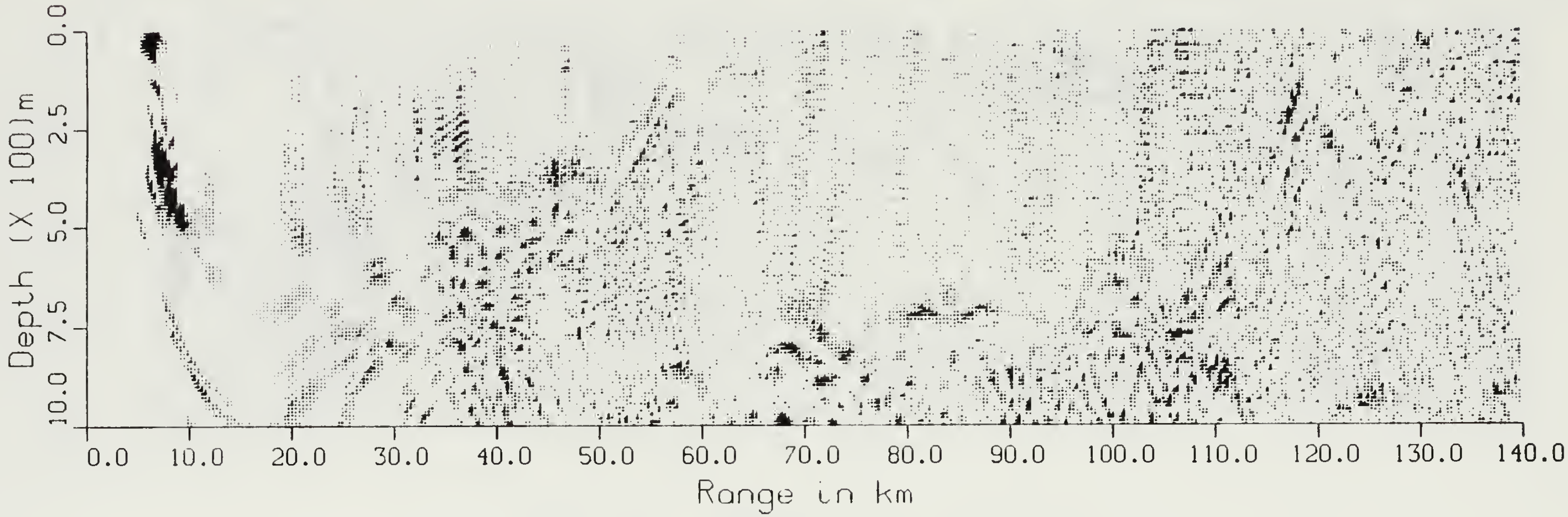

SOURCE DEPTH = 100M
GULF STREAM DIFF RES 2KM AND 25KM
Depth (X 100)m
0.0
2.5
5.0
7.5
10.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
120.0
130.0
140.0
Range in km


GULF STREAM DIFF RES 2KM AND 6KM
SOURCE DEPTH = 500 M
Depth (X 100)m
0.0
2.5
5.0
7.5
10.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
120.0
130.0
140.0
Range in km

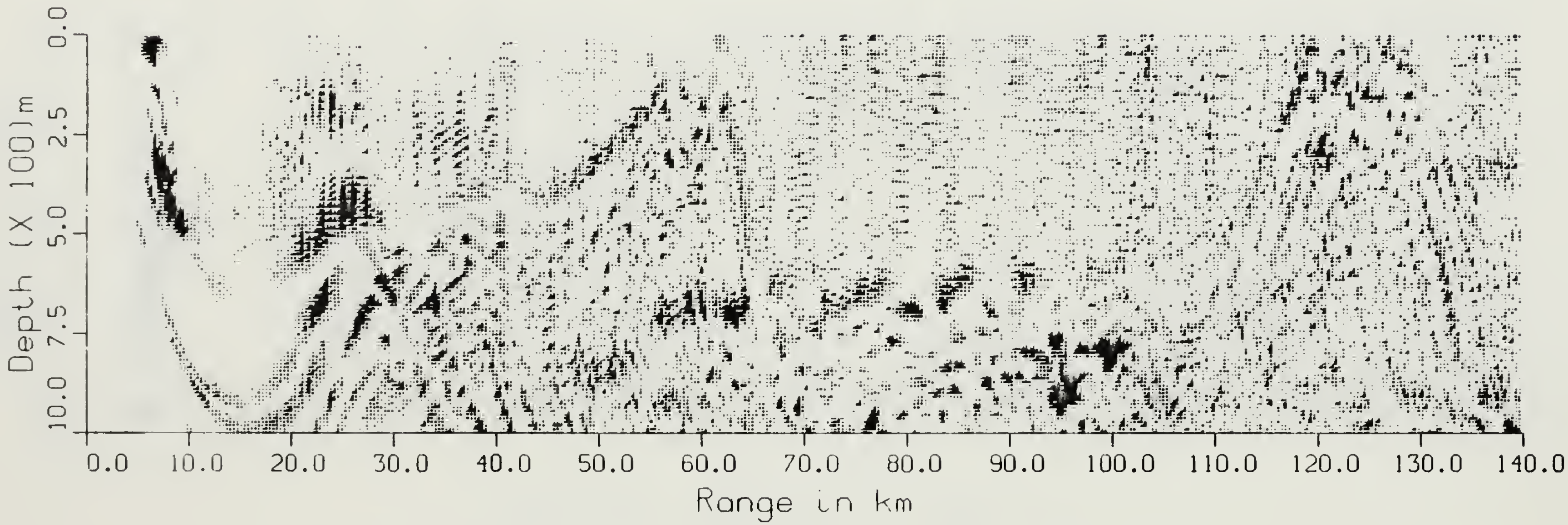
GULF STREAM DIFF RES 2KM AND 8KM
SOURCE DEPTH = 500 M



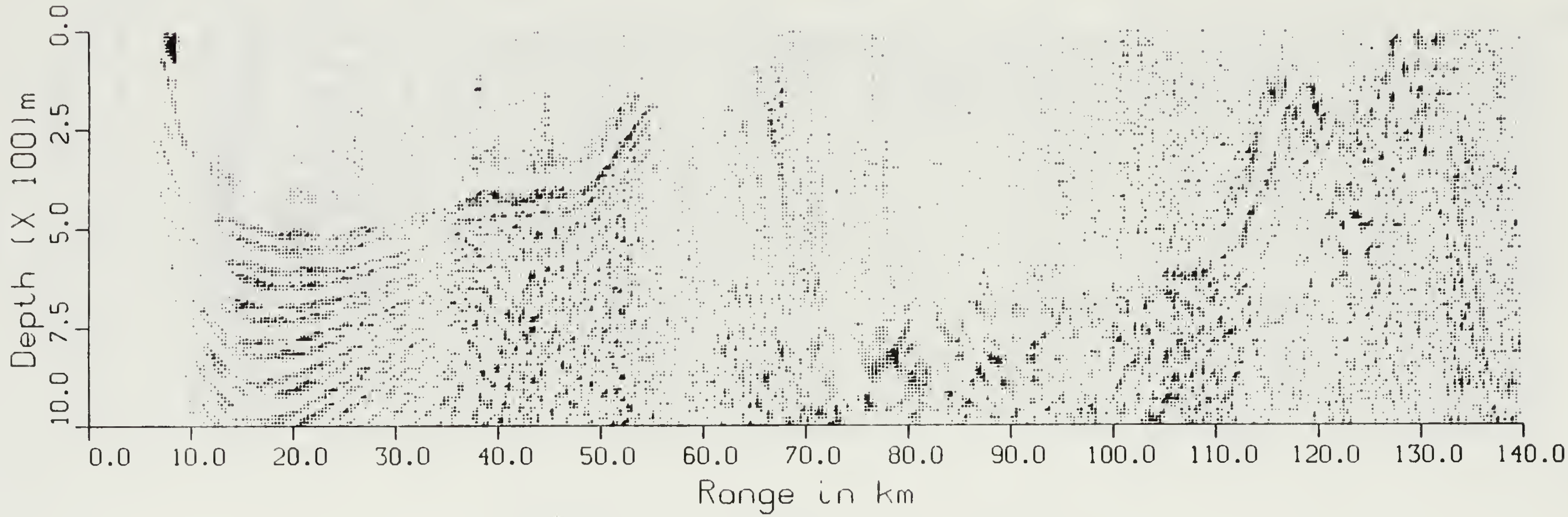
GULF STREAM DIFF RES 2KM AND 10KM
SOURCE DEPTH = 500 M



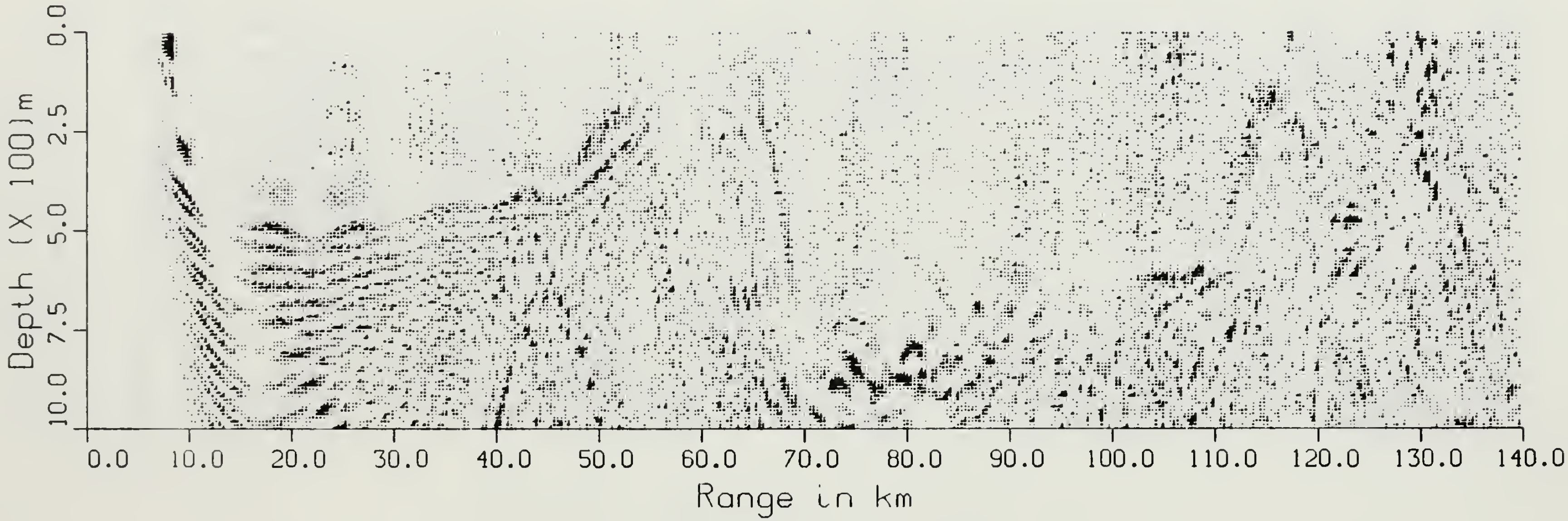
GULF STREAM DIFF RES 2KM AND 20KM
SOURCE DEPTH = 500 M

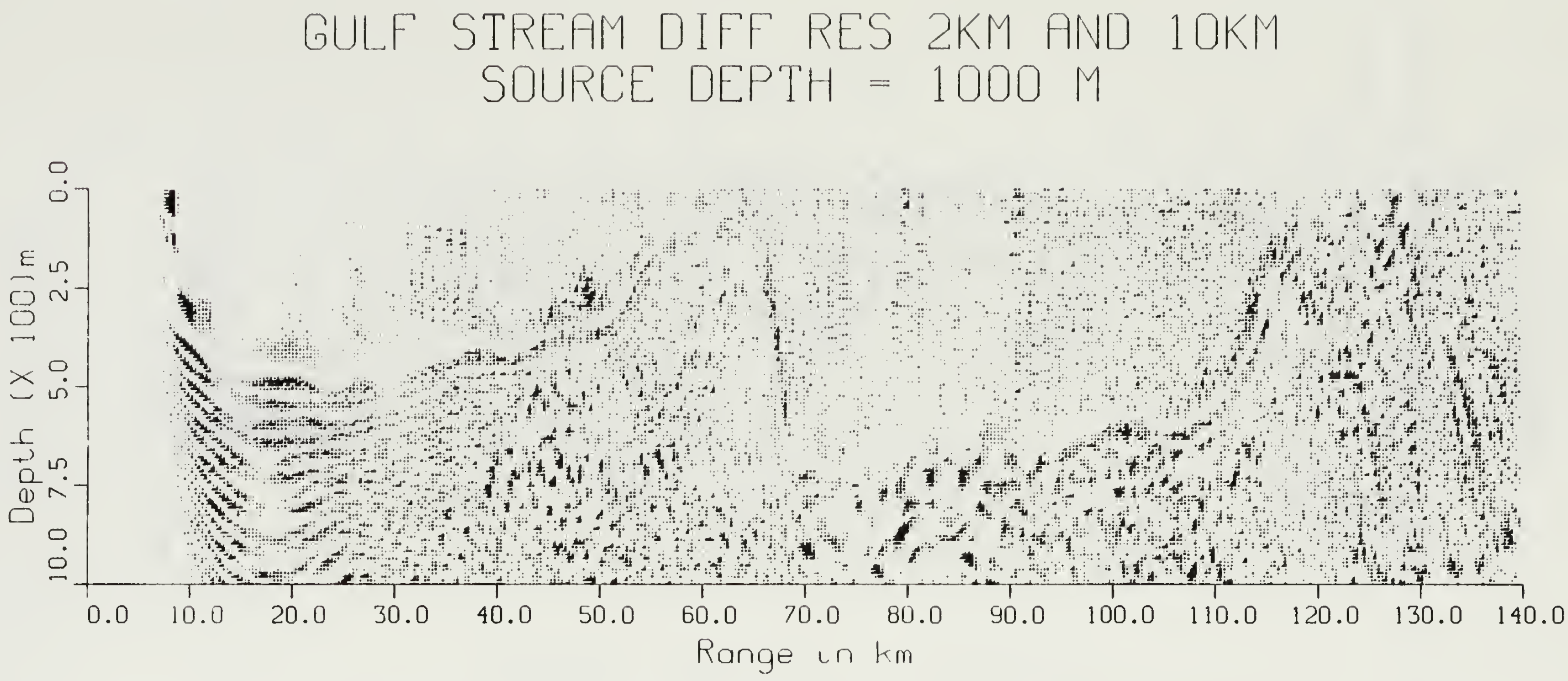


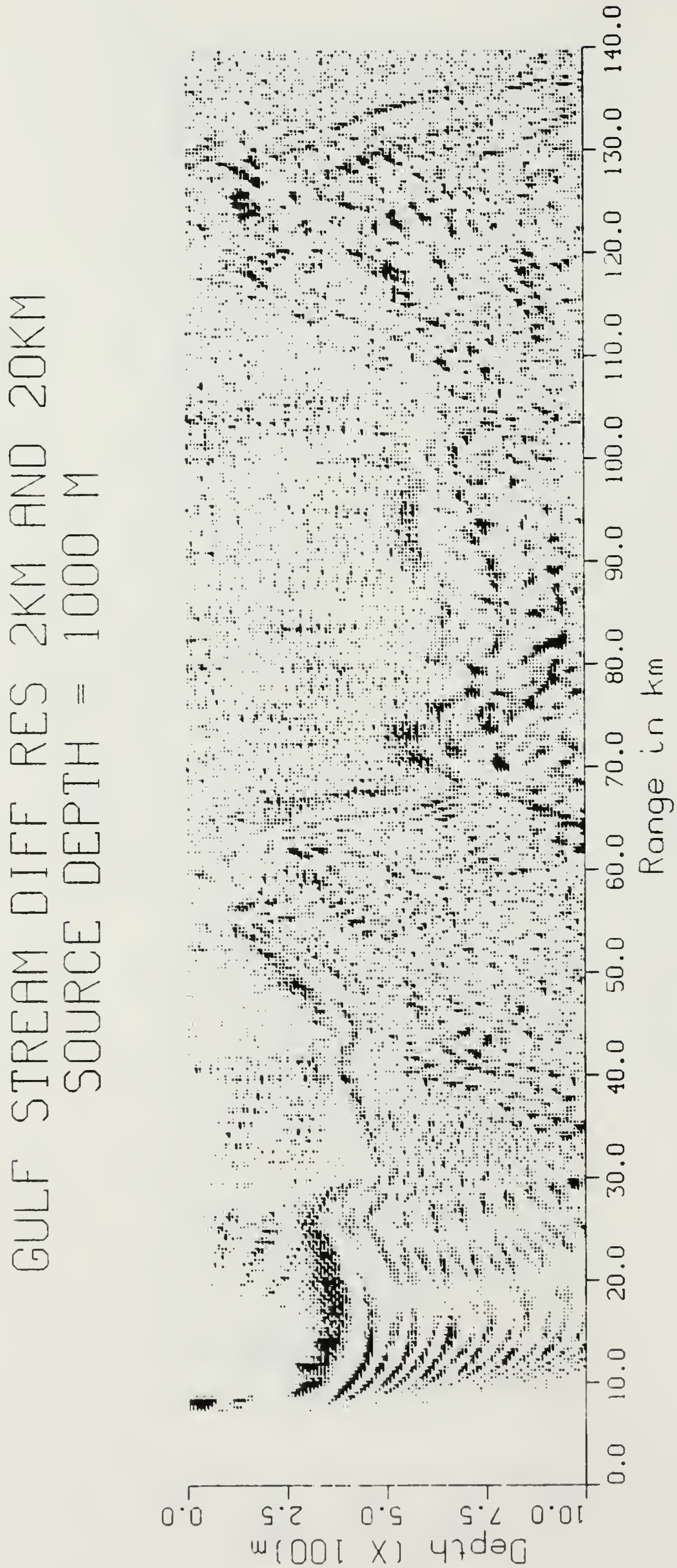
GULF STREAM DIFF RES 2KM AND 6KM
SOURCE DEPTH = 1000 M



GULF STREAM DIFF RES 2KM AND 8KM
SOURCE DEPTH = 1000 M



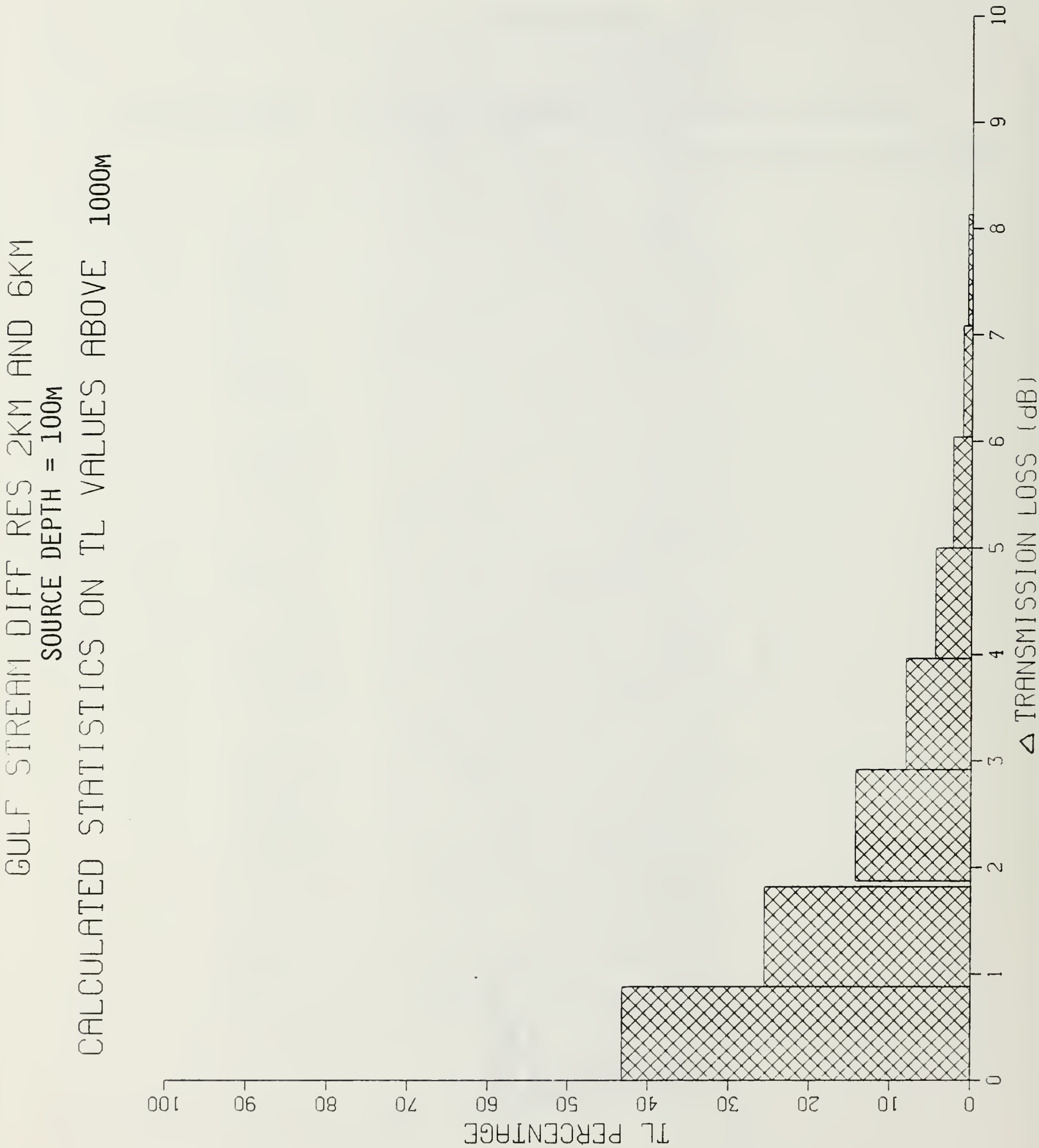

GULF STREAM DIFF RES 2KM AND 10KM
SOURCE DEPTH = 1000 M
Depth (X 100)m
0.0
2.5
5.0
7.5
10.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
120.0
130.0
140.0
Range in km

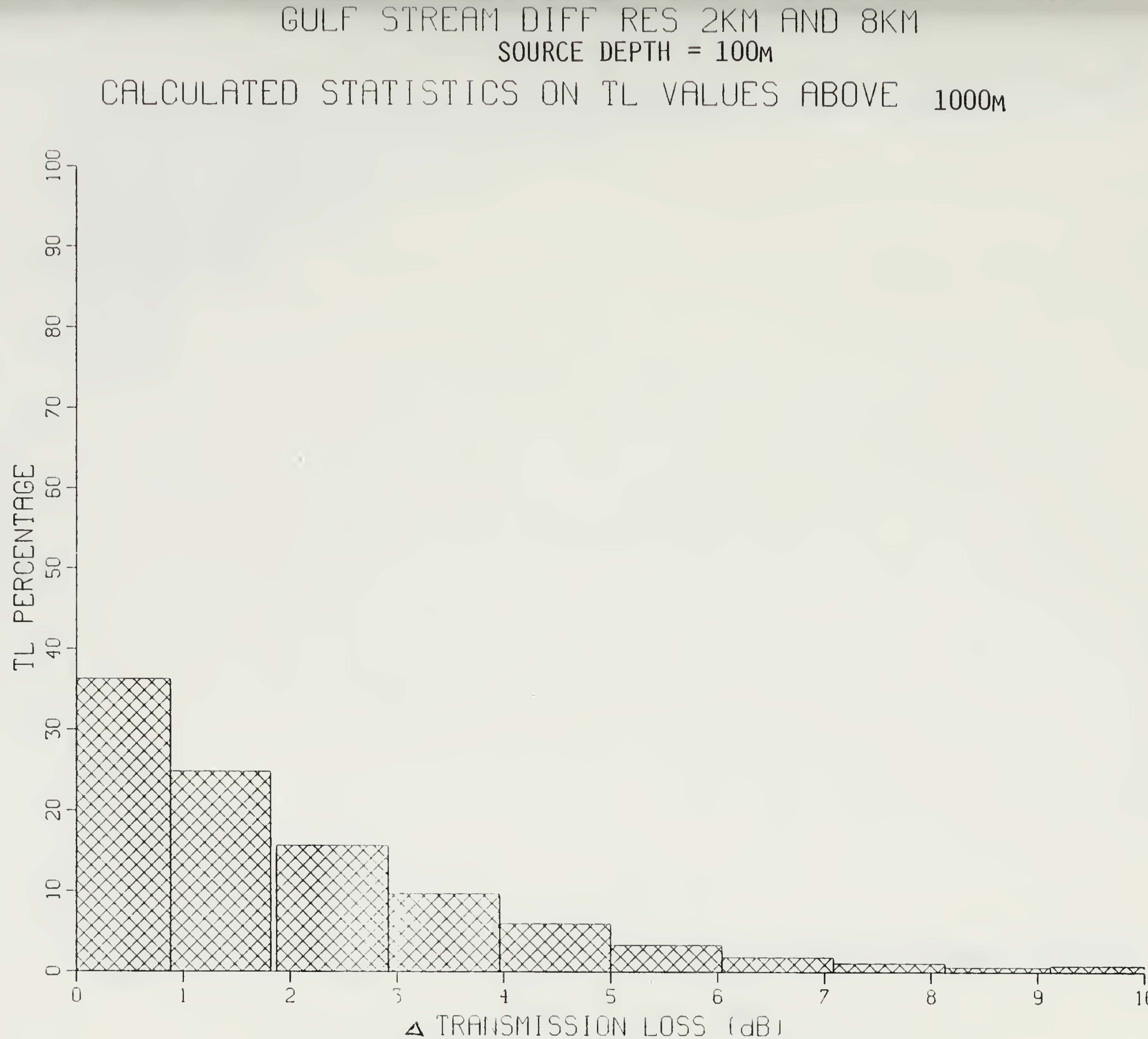

GULF STREAM DIFF RES 2KM AND 20KM
SOURCE DEPTH = 1000 M
Range in km
Depth (X 100)m
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
110.0
120.0
130.0
140.0
0.0
2.5
5.0
7.5
10.0

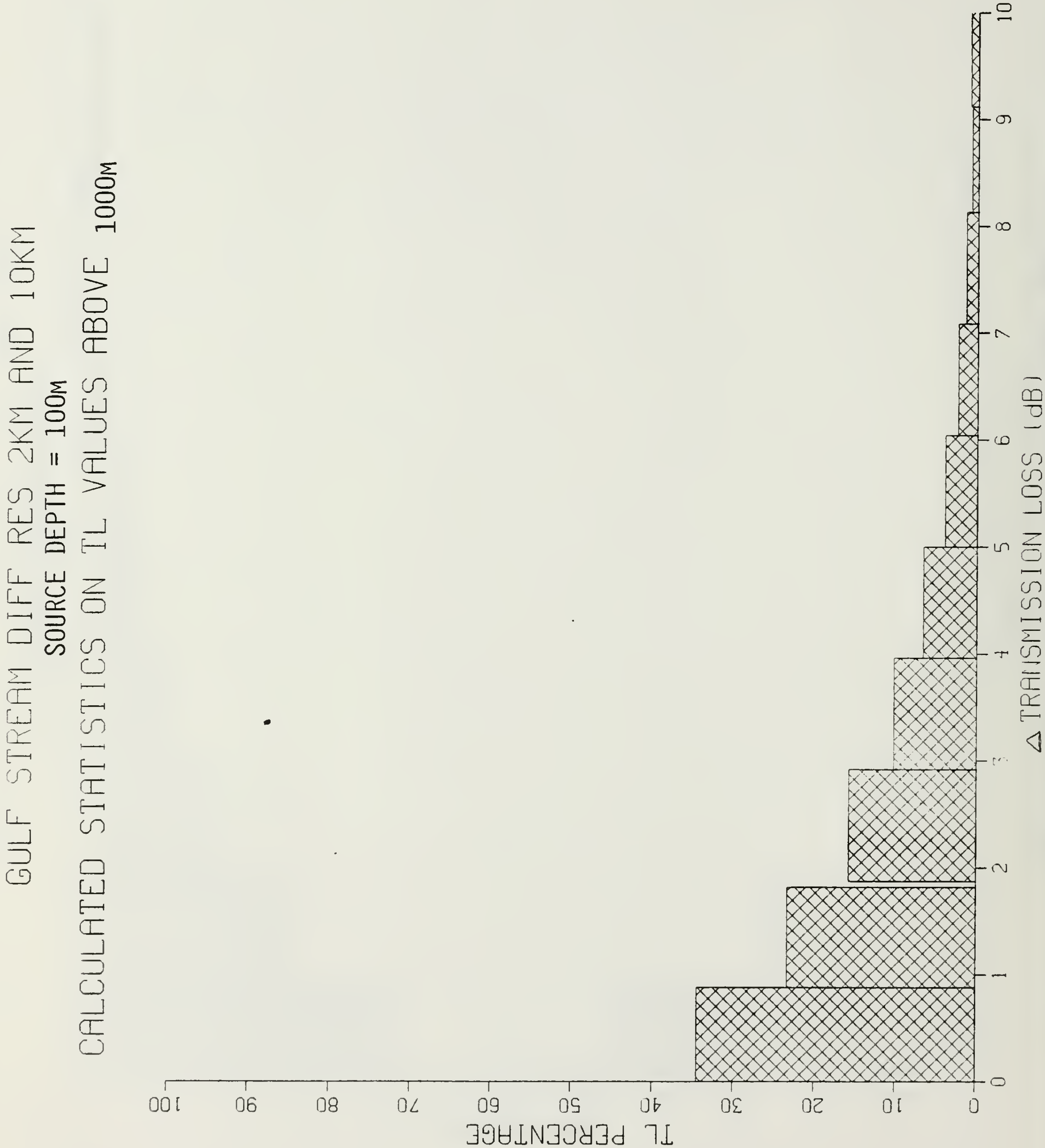
APPENDIX F

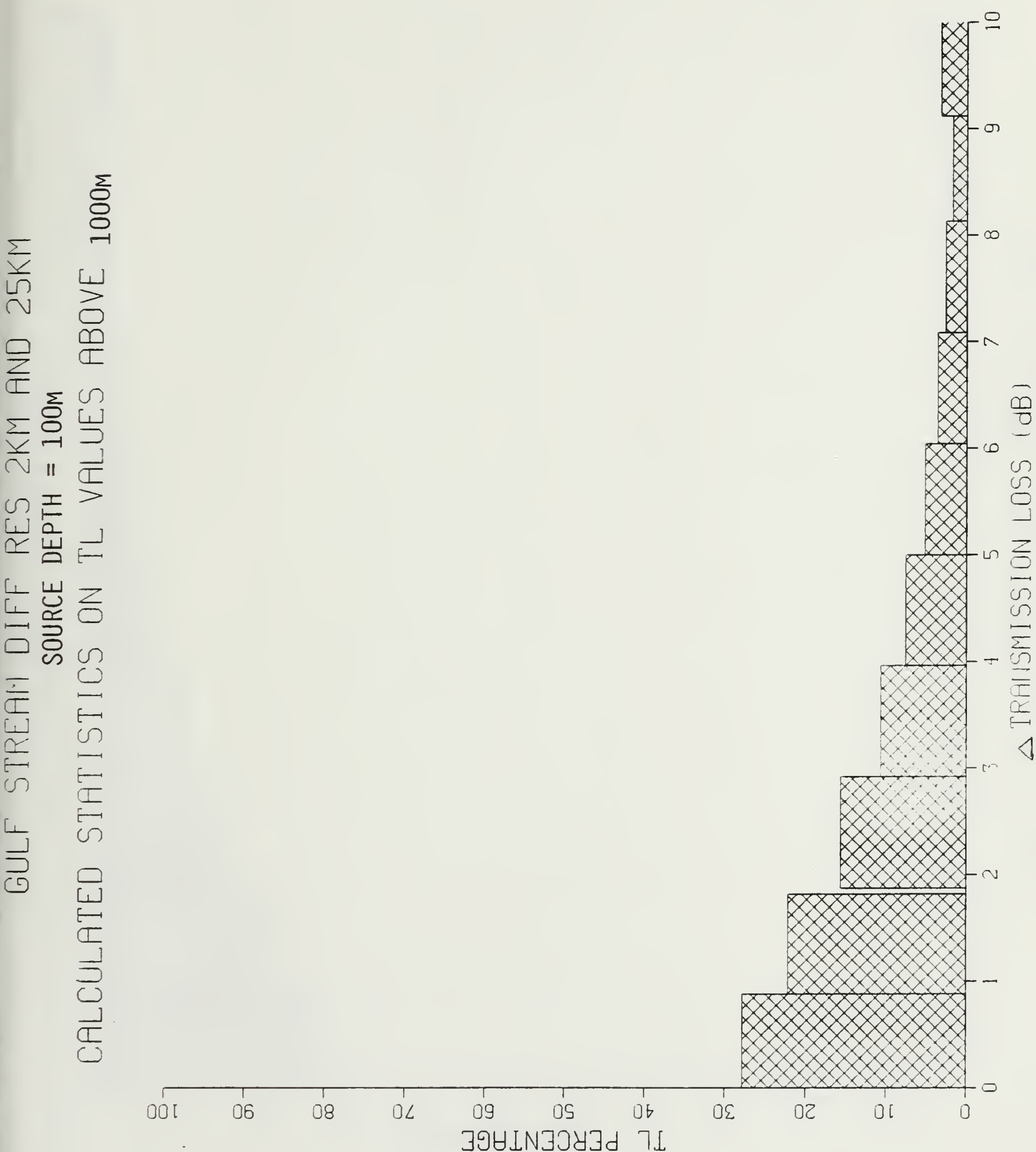
HISTOGRAMS

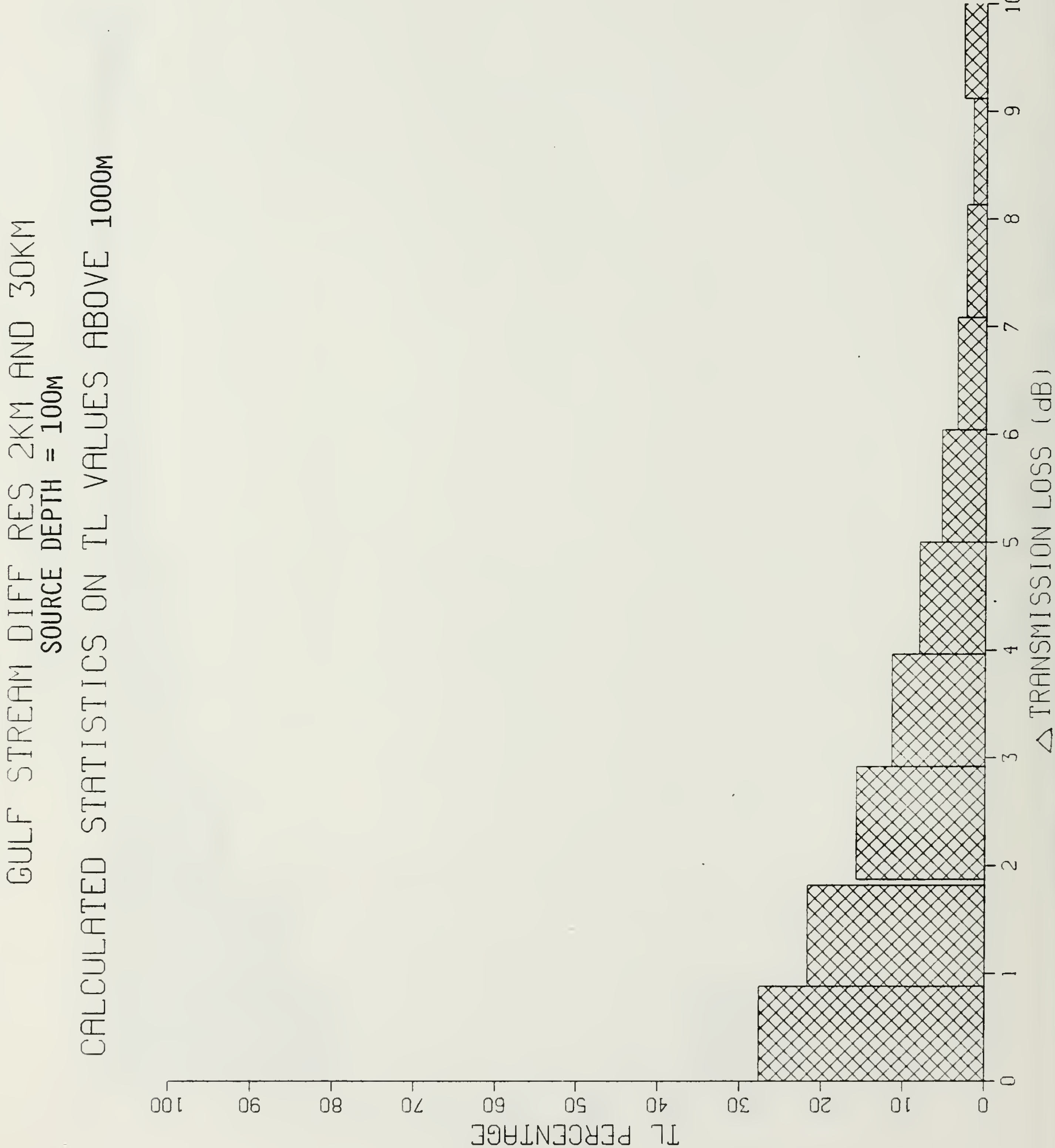
Enclosed are the histograms used for quantitative analysis in this study.


GULF STREAM DIFF RES 2KM AND 6KM
SOURCE DEPTH = 100M
CALCULATED STATISTICS ON TL VALUES ABOVE 1000M
TL PERCENTAGE
0
10
20
30
40
50
60
70
80
90
100
Δ TRANSMISSION LOSS (dB)
0
1
2
3
4
5
6
7
8
9
10


GULF STREAM DIFF RES 2KM AND 8KM
SOURCE DEPTH = 100M
CALCULATED STATISTICS ON TL VALUES ABOVE 1000M
TL PERCENTAGE
0
10
20
30
40
50
60
70
80
90
100
0
1
2
3
4
5
6
7
8
9
10
Δ TRANSMISSION LOSS (dB)


GULF STREAM DIFF RES 2KM AND 10KM
SOURCE DEPTH = 100M
CALCULATED STATISTICS ON TL VALUES ABOVE 1000M
TL PERCENTAGE
0
10
20
30
40
50
60
70
80
90
100
0
1
2
3
4
5
6
7
8
9
10
Δ TRANSMISSION LOSS (dB)

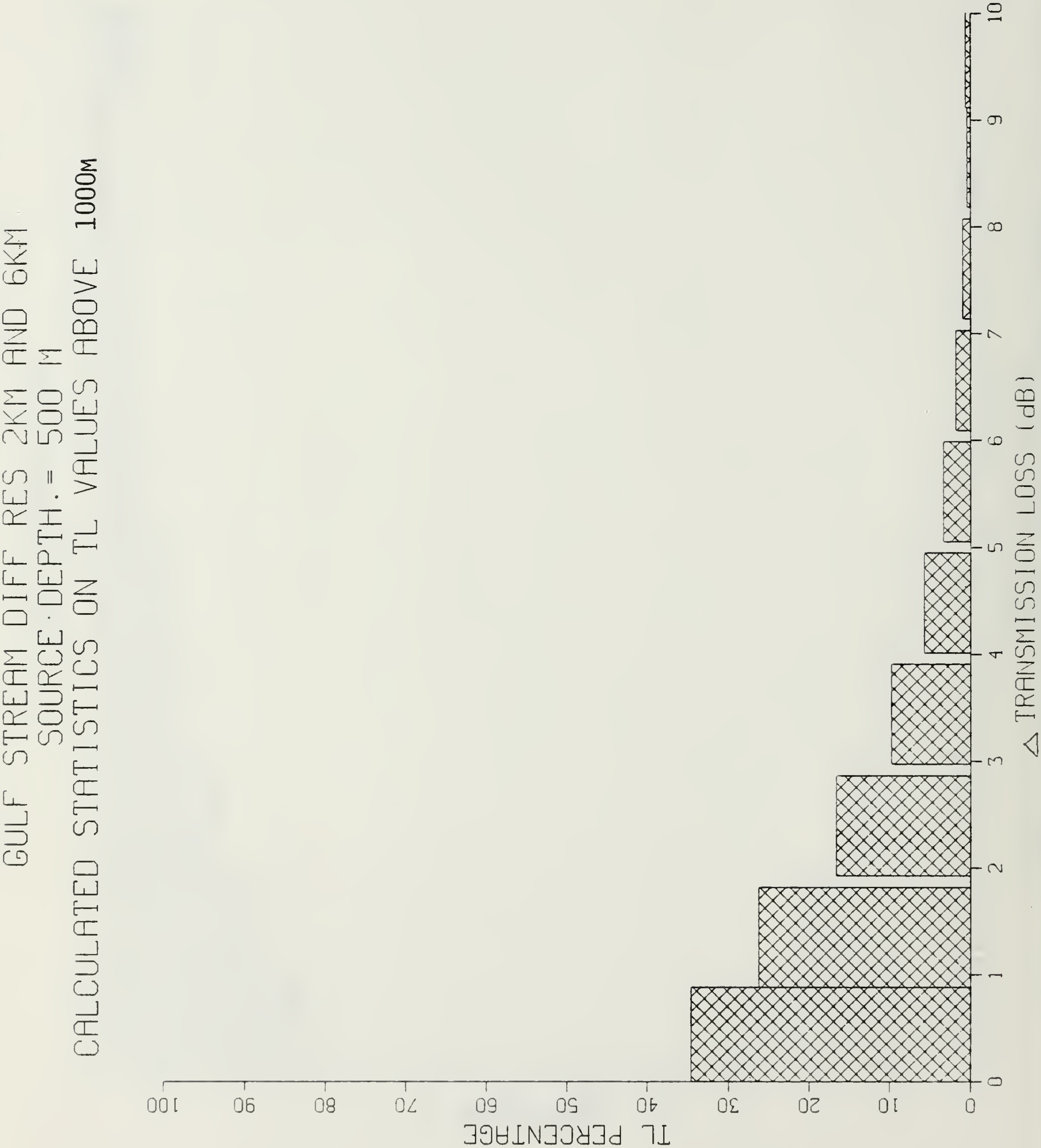

GULF STREAM DIFF RES 2KM AND 25KM
SOURCE DEPTH = 100M
CALCULATED STATISTICS ON TL VALUES ABOVE 1000M
TL PERCENTAGE
0
10
20
30
40
50
60
70
80
90
100
0
1
2
3
4
5
6
7
8
9
10
△ TRANSMISSION LOSS (dB)


GULF STREAM DIFF RES 2KM AND 30KM
SOURCE DEPTH = 100M
CALCULATED STATISTICS ON TL VALUES ABOVE 1000M
TL PERCENTAGE
△ TRANSMISSION LOSS (dB)
0
10
20
30
40
50
60
70
80
90
100
1
2
3
4
5
6
7
8
9

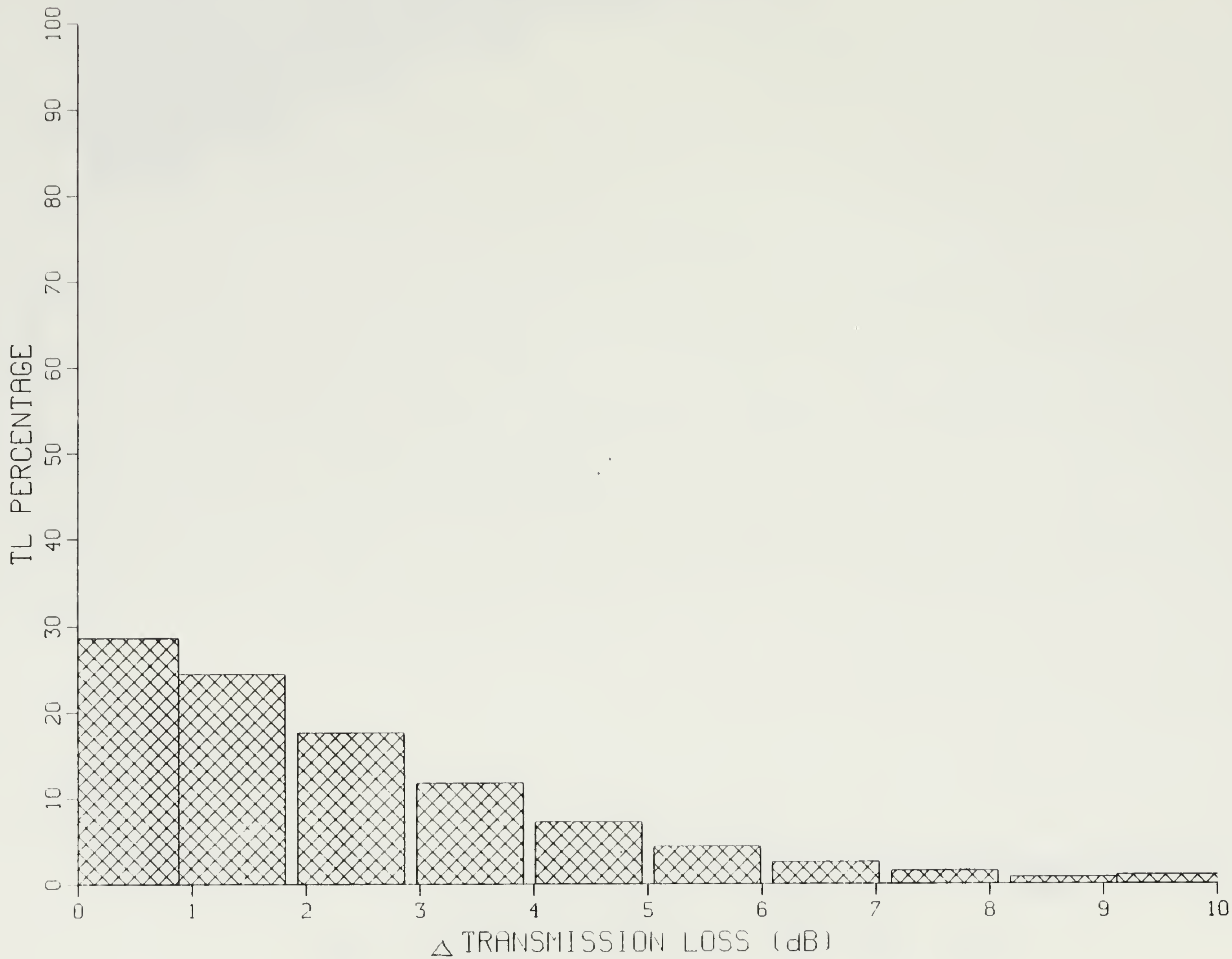
GULF STREAM DIFF RES 2KM AND 60KM

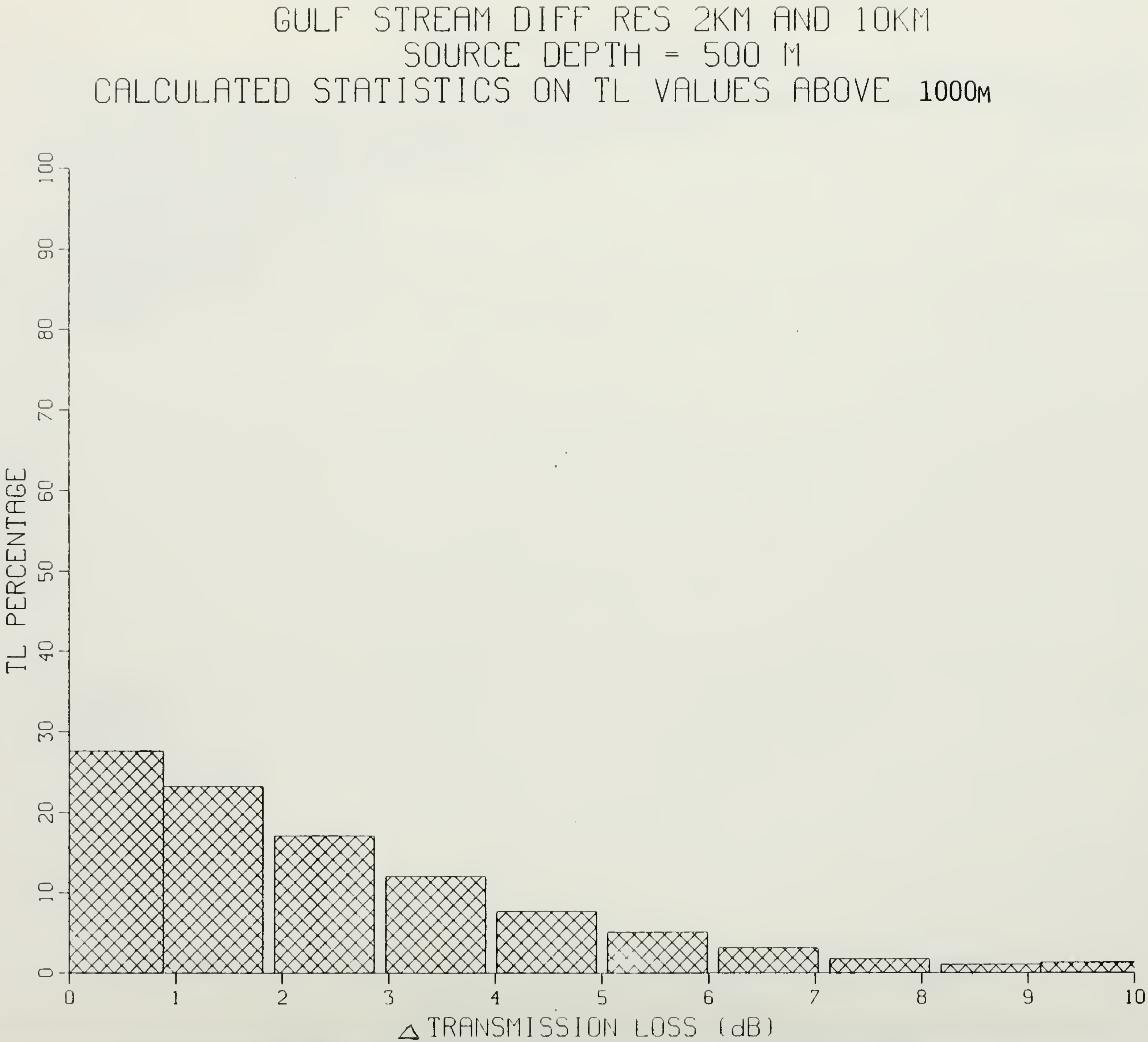
SOURCE DEPTH = 100M

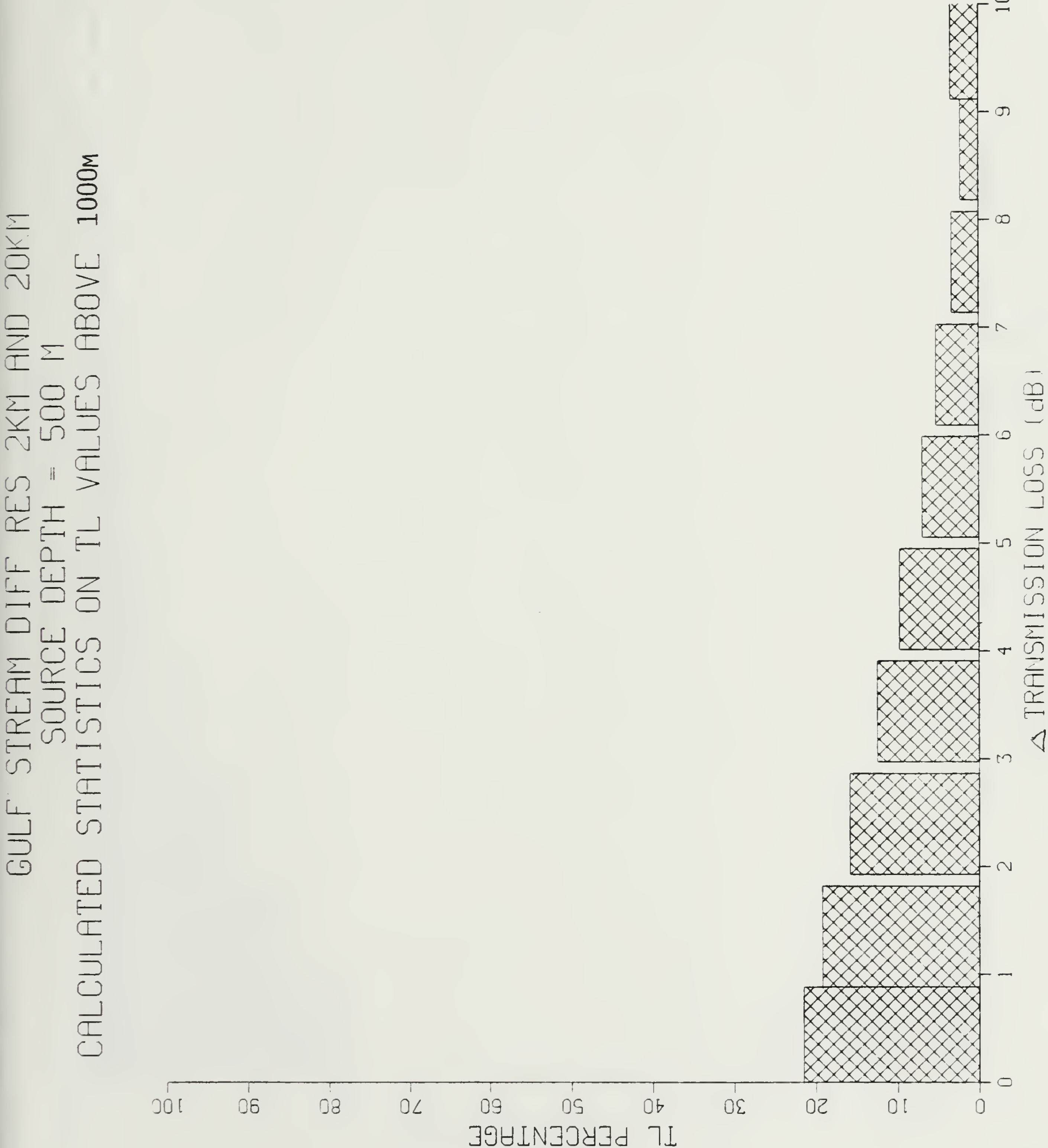
CALCULATED STATISTICS ON TL VALUES ABOVE 1000M


GULF STREAM DIFF RES 2KM AND 6KM
SOURCE DEPTH.= 500 M
CALCULATED STATISTICS ON TL VALUES ABOVE 1000M
TL PERCENTAGE
0
10
20
30
40
50
60
70
80
90
100
△ TRANSMISSION LOSS (dB)
0
1
2
3
4
5
6
7
8
9
10

GULF STREAM DIFF RES 2KM AND 8KM
SOURCE DEPTH = 500 M
CALCULATED STATISTICS ON TL VALUES ABOVE 1000M

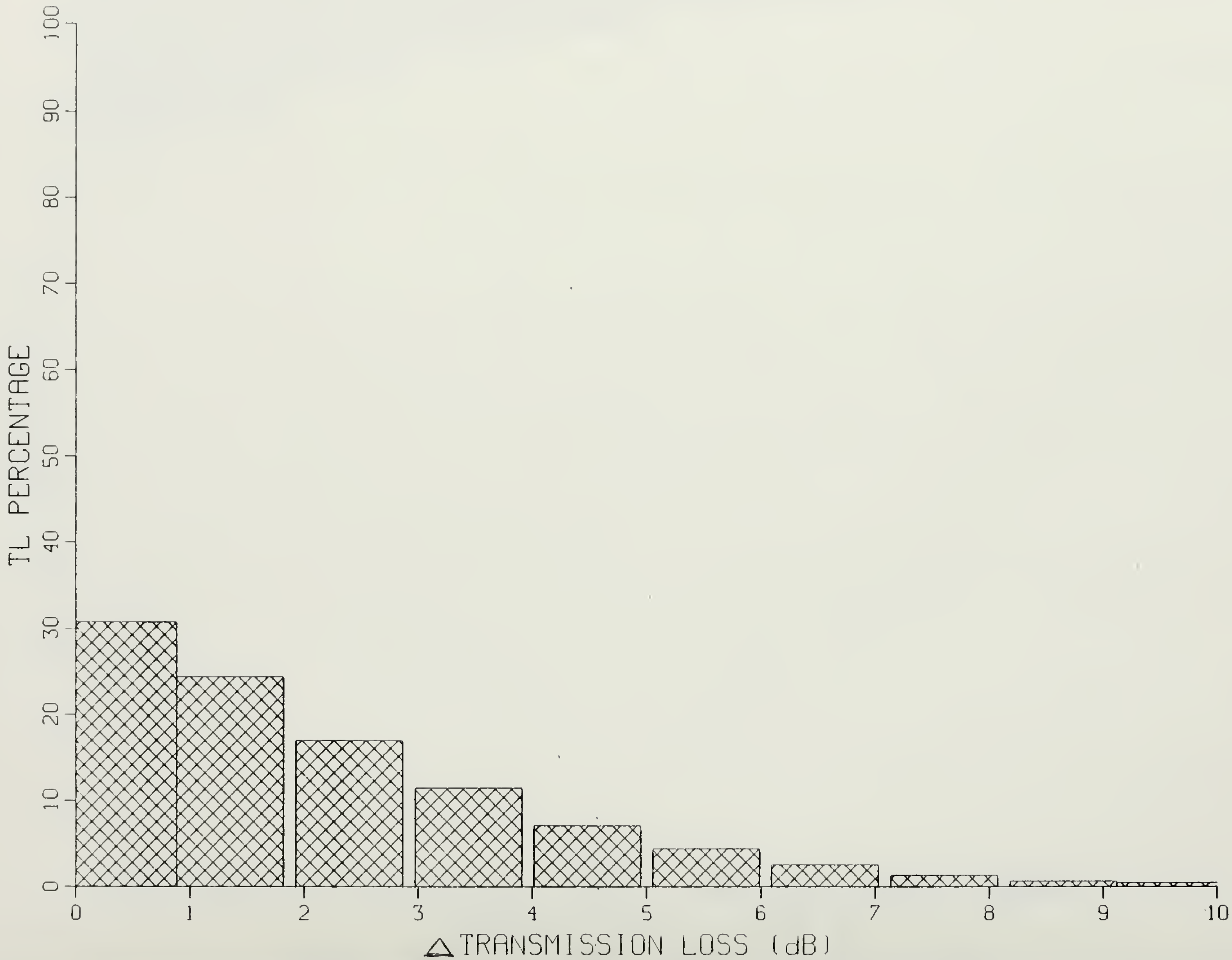



GULF STREAM DIFF RES 2KM AND 10KM
SOURCE DEPTH = 500 M
CALCULATED STATISTICS ON TL VALUES ABOVE 1000M
TL PERCENTAGE
0
10
20
30
40
50
60
70
80
90
100
0
1
2
3
4
5
6
7
8
9
10
△ TRANSMISSION LOSS (dB)

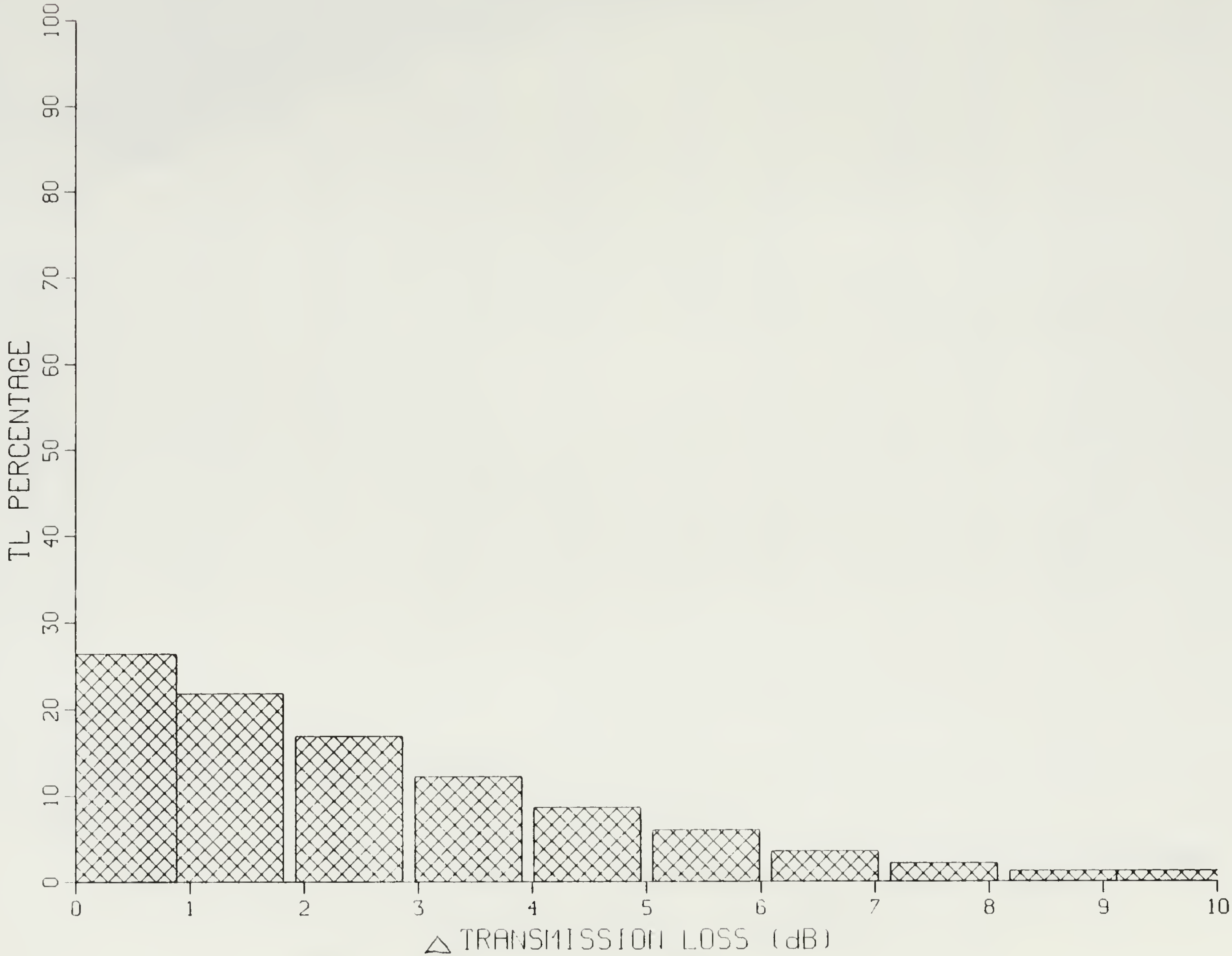


GULF STREAM DIFF RES 2KM AND 20KM
SOURCE DEPTH = 500 M
CALCULATED STATISTICS ON TL VALUES ABOVE 1000M
TL PERCENTAGE
0
10
20
30
40
50
60
70
80
90
100
△ TRANSMISSION LOSS (dB)
0
1
2
3
4
5
6
7
8
9
10

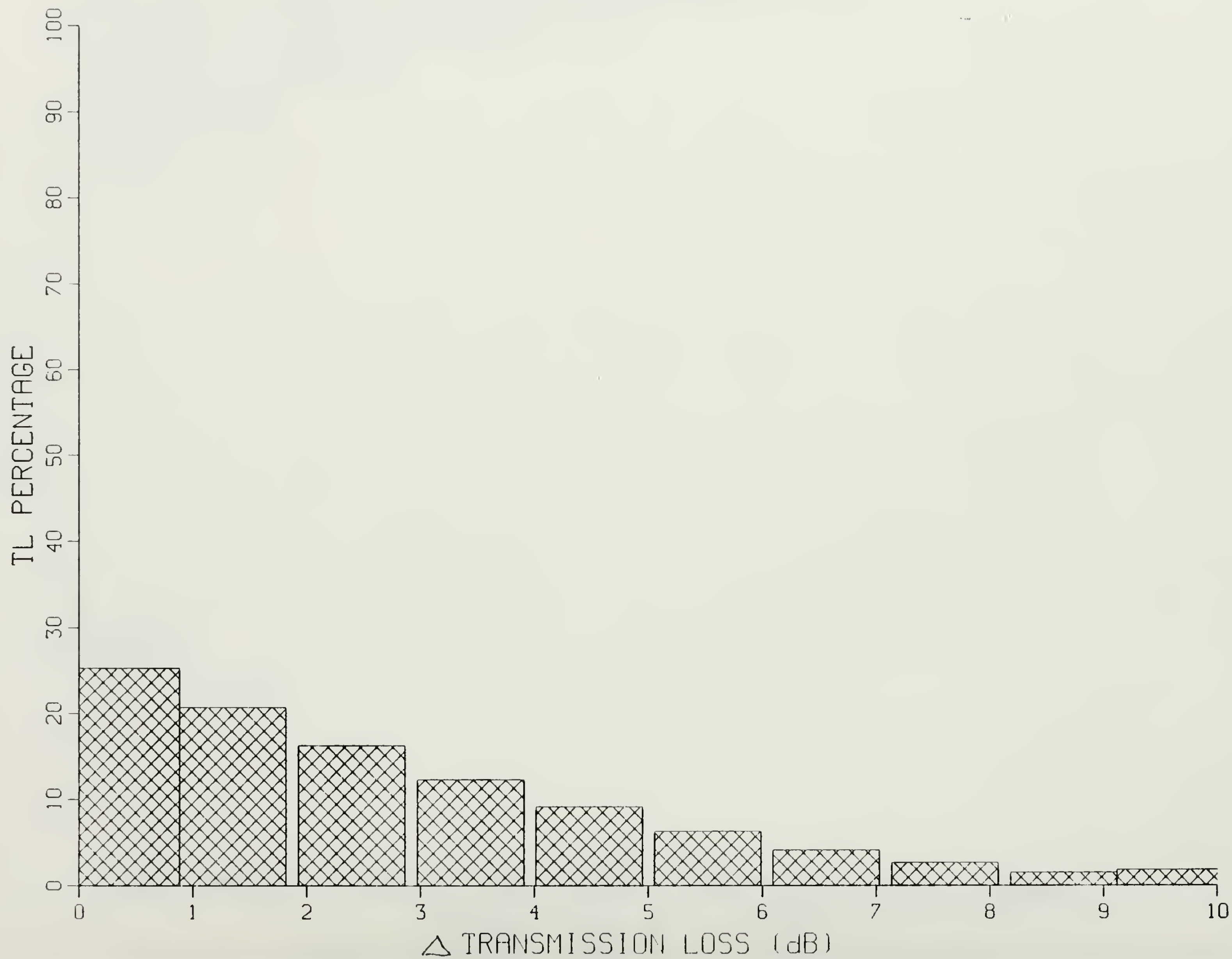
GULF STREAM DIFF RES 2KM AND 6KM
SOURCE DEPTH = 1000 M
CALCULATED STATISTICS ON TL VALUES ABOVE 1000M



GULF STREAM DIFF RES 2KM AND 8KM
SOURCE DEPTH = 1000 M
CALCULATED STATISTICS ON TL VALUES ABOVE 1000M



GULF STREAM DIFF RES 2KM AND 10KM
SOURCE DEPTH = 1000 M
CALCULATED STATISTICS ON TL VALUES ABOVE 1000M



GULF STREAM DIFF RES 2KM AND 20KM
SOURCE DEPTH = 1000 M
CALCULATED STATISTICS ON TL VALUES ABOVE 1000M

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2. NUSC Technical Report 6659, IFD--An Implicit Finite-Difference Computer Model for Solving the Parabolic Equation, by D. Lee and G. Botseas, 27 May 1982.

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5. Siegmann, W.L., Kriegsmann, G.A., Lee, D., "A Wide-Angle Three Dimensional Parabolic Wave Equation," JASA, 78(2), pp. 659-672, August 1985.

6. Tappert, F.D., Lee, D., "A Range Refraction Parabolic Equation," JASA, 76(6), pp. 1797-1804, December 1984.

7. NPS Technical Report 61-83-002, An Introduction to the Parabolic Equation for Acoustic Propagation, by A.B. Coppens, November 1982.

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